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Open File Report 6072

Physical Evaluation and Assessment of Bedrock Aggregate Resource Potential, North Shore of Lake Superior

2001

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ONTARIO GEOLOGICAL SURVEY

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Physical Evaluation and Assessment of Bedrock Aggregate Resource Potential, North Shore of Lake Superior

by

Jagger Hims Limited, Clayton Research Limited and Agritrans Limited

2001

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ABSTRACT

A study of the geology of the bedrock along the entire north shore of Lake Superior was conducted for a distance of 5 km inland in order to identify potential sources of high quality aggregate. Fifteen candidate areas were identified on the basis of a geological literature search and each was field checked to confirm overall potential to produce high quality aggregate. Samples were taken for selected quality testing. Testing confirmed that there are a variety of intrusions, dikes and sills in the study area potentially capable of producing high quality aggregates. A review of marine transportation on the north shore of Lake Superior confirms the existence of 2 operational deep water ports, several inactive facilities that might be upgraded and some sites where deep water marine shipping facilities might be constructed. Current costs for shipping aggregate (2000 rates in Canadian dollars) via bulk freighter are approximately $10 to $12 per tonne to Chicago or Toronto.

A review of general supply and economic factors pertaining to the establishment of an aggregate quarry on lake Superior was conducted. Several concerns and advantages have been identified. A preliminary review of markets for high quality aggregate was conducted. It is expected that high quality aggregate will become a "niche" market in many port areas on the Great Lakes, but volumes required will be modest. Potential larger and more diverse market areas have been identified in the Greater Toronto Area and in the Chicago/Gary area which may have the potential to import large quantities of aggregate in the foreseeable future. The delivered price of high quality aggregate in the Toronto area is currently estimated to be $25 to $30 per tonne and Lake Superior aggregate could potentially be delivered for $25 to $35 per tonne at this time. Other aggregate products currently command lower prices, but these prices are expected to rise as local supplies are depleted. Chicago currently has an adequate supply of local aggregate, but approximately one half of the local supply is expected to be depleted in approximately a decade. The resulting cost increases may provide an opportunity for Lake Superior aggregate to supply the Chicago area market on a significant scale.

1.0 Introduction

1.1 BACKGROUND

This report documents the findings of a geological and economic assessment of potential high quality bedrock aggregate resources along the north shore of Lake Superior. The study was commissioned by the Ministry of Northern Development and Mines (MNDM), as it has been recognized that high quality bedrock resources exist in the Lake Superior region which could be transported via the Great Lakes to markets in southern Ontario and the central United States.

A trend has been observed in the aggregate industry towards the use of large, consistent and predictable bedrock resources to produce high quality aggregates. Due to escalating costs for licensing and the declining availability of high quality aggregates close to southern Ontario and neighbouring markets, aggregate producers have started to examine the potential for aggregate resources in other areas that are strategically located for efficient bulk transport.

Aggregate producers have had success using marine transport to distribute aggregate from a number of sites on the Great Lakes. Currently in Ontario, high quality aggregate resources located along the North Channel of Lake Huron are being extracted and shipped to markets by lake freighter. A quarry at the western tip of Manitoulin Island is one of the larger producers in Canada and is a source of aggregate products that are shipped to a number of locations in the Great Lakes region. Historically, aggregates and commercial stone products have been shipped from quarries located along the north shore of Lake Superior and from some of its off-shore islands.

1.2 DEFINITIONS

People from many backgrounds discuss aggregates in a variety of contexts and some of the terms that are used to discuss aggregates have taken on slightly different meanings in different jurisdictions. The terms used in the Lake Superior study are defined below so that the reader has a clear understanding of how the terms are used within the context of this report.

Aggregate: a broad term that includes all types and qualities of products derived from natural sand and gravel, quarried rock, slag or recycled materials. Materials such as 'traprock', concrete stone, asphalt stone and sand, coarse and fine granular mixes, sub-base and base course materials, various sand products, sand fill and a wide variety of non-specification and specialty products are included.

Crushed Rock or Crushed Stone: any type of rock that has been extracted and crushed to produce an aggregate product. Bedrock is the normal source for crushed rock but it is possible to produce crushed rock by selectively mining and crushing boulders from a natural gravel deposit. Carbonate rocks (limestone and dolostone) are the most common sources of crushed rock but granite (and rocks of similar composition) and diabases (and other similar 'traprocks') are important rock sources.

High quality (crushed) rock: Quality which satisfies standards such as those used for paving major roads and highways or for use in high specification concrete. Source rocks are generally granites or

diabases which meet very high test and performance levels for chemical durability, physical durability and (where applicable) skid resistance.

1.3 OBJECTIVES AND SCOPE

The study was focused on one fundamental question – *Is it feasible to mine high quality aggregate in the Lake Superior area for sale in central Canada and the United States?* From this question, the following principal objectives for the study were derived.

- To identify and investigate candidate resource areas containing accessible bedrock units with potential to produce high quality aggregates.
- To evaluate the economics of transporting aggregates to market using marine or rail transport.
- To evaluate the economics of developing a commercial scale extractive operation on the north shore of Lake Superior.
- To assess the geologic and economic information and document the findings of the study.

The study is, therefore, an assessment of the aggregate resource potential of bedrock along the north shore of Lake Superior which can be used as input into land use strategies for the region (Chudleigh 2000).

1.4 STUDY APPROACH AND METHODOLOGY

A team of geology, transportation and economics analysts was assembled to complete the study. The approach started with a review and interpretation of published geological data, such as bedrock geology maps and reports, engineering geology terrain studies and aggregate resource inventories. These data were considered, along with recent experience in testing similar rocks in other areas of Ontario, in order to select a group of candidate resource areas in the study area. Municipal planning agencies were also contacted to provide preliminary land use information and background for input into candidate resource area selection and assessment. Fifteen candidate areas were selected on the basis of the literature review.

The 15 candidate areas were examined, photographed and sampled in the field. Field observations were recorded on visual assessment check sheets that included the following information: assessment station identification; GPS coordinates in Universal Transverse Mercator (UTM) projection; location description; photograph description; geological description; exposure description; and access and transportation factors. Assessment station locations and general field observations were recorded on a working set of 1:50 000 scale NTS topographic base maps.

Representative 68 kg bulk samples of the bedrock were taken from selected exposures using sledgehammers and chisels. Samples were extracted, wherever possible, from man-made exposures to obtain fresh material. Care was taken to avoid geological factors (discussed in Section 2.4) which would adversely affect test data so that the maximum potential of the rock was determined.

Bulk rock samples were submitted to Peto MacCallum Limited of Hamilton for laboratory physical quality testing. The samples were identified by a field number and a separate laboratory reference number and were crushed at the testing laboratory using a Braun International (Bico) Chipmunk jaw crusher (Type WD).

Selected samples were submitted to the MTO laboratory in Downsview, Ontario for Polished Stone Value (PSV) testing. Results of the PSV testing are summarized in Appendix A.

Laboratory test results were assessed using the following Ontario Special Provision Specifications for aggregate quality:

- Special Provision 110F11 (concrete)
- Special Provision 110F12 (asphalt)
- Special Provision 110F13 (granular)

A review transportation factors related to shipping aggregate from the north shore of Lake Superior was completed using available year 2000 transportation rates, topographic and hydrographic mapping and field data. Primary emphasis was placed on marine transport but transportation by rail was also considered.

Finally, an economic assessment was completed which considered supply for potential resource areas and aggregate demand factors in selected United States and Ontario markets.

1.5 LOCATION, PHYSIOGRAPHY AND ACCESS

The study area is a 5 km wide corridor along the north shore of Lake Superior between Sault Ste. Marie and the Canada-United States border southwest of Thunder Bay (Figure 1-1). This area encompasses approximately 800 km of Lake Superior coastline and also includes several off-shore islands.

The study area lies entirely within the Canadian Precambrian Shield, a broad dome-like structure of resistant rock bordered by the Hudson Bay Lowland to the north and the St. Lawrence Lowland to the south. The physiography of the Canadian Shield has been influenced by a wide range of geological processes spanning billions of years. These include "volcanism, sedimentation, plutonism, faulting, mountain building, erosion, burial, uplift, weathering and glaciation" (Thurston 1991a). Glaciation was the most recent process to modify the landscape. The effect of advancing and retreating glaciers during the ice age 100 000 to 7000 years ago was to scour large areas of the bedrock and deposit irregularly located, unconsolidated masses of gravel, sand, silt and clay.

The Canadian Shield is divided into several broad physiographic regions (Bostock 1970), 2 of which span the study area. The Abitibi Upland, which extends from Sault Ste. Marie to approximately Nipigon, and the Port Arthur Hills, located between Nipigon to the international border. The Abitibi Upland is typically a region with a rocky landscape covered by glacial deposits and numerous lakes. The Port Arthur Hills is a region of steep ridges and mesa landforms, which are a result of 2 distinctly different types of mafic igneous intrusions into softer less resistant sedimentary rocks. Low-lying areas between the hills often contain thick glaciolacustrine clay-silt

Figure 1-1: Study Area

deposits. Maximum ground elevations in both physiographic regions are approximately 450 m above sea level, or approximately 265 m above Lake Superior

Primary access to the study area is provided by Highways 17, 11 and 61. There are also a number of secondary highways, regional roads, rural roads and logging trails that provide secondary access. Significant parts of the study area are not accessible by road and other modes of access, such as boat or helicopter, were used. Commercial centers along the lakeshore provide equipment and services.

1.6 PREVIOUS WORK AND REFERENCES

The geology of the study area has been mapped at various levels of detail ranging from 1:15 840 township scale maps to 1:1 000 000 provincial scale maps. Complete geological map coverage is available.

Numerous reports have been published on the bedrock geology of the Lake Superior region. This follows decades of mapping and mineral exploration in the province. The "Geology of Ontario" (Ontario Geological Survey 1991a) provides a broad description of the regional geology and physiography for the study area. The reader is referred to this document and to the various detailed maps and geological reports for additional information.

Surficial geology is summarized in Northern Ontario Engineering Geology Terrain Studies which are available for the entire study area (Gartner 1979a, 1979b; Gartner and McQuay 1979, 1980; McQuay, 1980a, 1980b, 1980c; Mollard and Mollard 1981a, 1981b, 1983) and from the Quaternary Geology of Ontario (Barnett 1992) and associated maps (Barnett et al. 1991a, 1991b) as well as Boissonneau (1965a, 1965b). Aggregate Resources Inventory Papers (ARIPs) are also available for Hemlo (Ontario Geological Survey 1985a) and Sault Ste. Marie (Ontario Geological Survey 1985b).

2.0 Regional Geology and Aggregate Potential

2.1 GEOLOGIC DIVISIONS

The Lake Superior region has been subdivided into 3 major geologic divisions differentiated with respect to their age: the oldest, Archean rocks of the Superior Geologic Province that were formed more than 2.5 billion years ago; the Proterozoic rocks of the Southern Geologic Province that were formed between 2.5 billion and 570 million years ago; and the overlying Quaternary (glacial) deposits which relate largely to the last 20 000 years. The 2 bedrock units represent some of the oldest rocks on earth and the Quaternary deposits represent relatively recent geologic events. There are no known rocks in the study area which relate to the many millions of years between the deposition of the 2 bedrock groups and the recent Quaternary deposits.

The geologic divisions above are further divided into units and subunits containing the various rock types. These units are described in Table 2-1 and are discussed in more detail below.

TABLE 2-1: GEOLOGIC DIVISIONS
PHYSICAL EVALUATION AND ASSESSMENT OF BEDROCK AGGREGATE POTENTIAL
NORTH SHORE OF LAKE SUPERIOR

Geologic Division	Unit Name	Subunit	Geological Description	Occurrence	Comments
Surficial Deposits	Quaternary deposits	Recent	Swamp and stream deposits	Throughout study area	
		Pleistocene	Glacial drift, gravel, sand, silt, clay	Throughout study area	Major current and historical source of aggregate in study area.
Proterozoic Southern Province	Keweenawan Supergroup	Jacobsville Group	Quartz sandstone	Sault Ste. Marie, Goulais Bay, Batchawana Bay	Used for building stone. Potential for use as aggregate. Potentially reactive in concrete.
		Oronto Group	Quartz sandstone, conglomerate, shale	Mica Bay area	Rare occurrence in study area.
		Mamainse Point Formation	Basalt, rhyolite, conglomerate	Mamainse Point	Low aggregate potential.
		Mafic Intrusions	Diabase, gabbro, anorthosite	Intrusions between Nipigon Bay and Pigeon River, Pukaskwa dikes.	Fair to excellent aggregate potential.
		Osler Group	Quartz-feldspar porphyry, basalt, argillite, sandstone, conglomerate	Black Bay Peninsula, St. Ignace and adjacent islands	Variable rocks.
	Port Coldwell Alkalic Complex		Syenite, gabbro	Marathon, Port Coldwell	Used for building stone. Variable aggregate potential.
	Pre-Keweenawan	Sibley Group	Red shale and mudstone, sandy to clayey dolostone, quartz sandstone, conglomerate	Sibley and Black Bay Peninsulas, Nipigon area	Used for building stone and industrial applications. Generally low aggregate potential.
		Animikie Group	Shale, greywacke, conglomerate, carbonates, iron formation, tuff	Thunder Bay to Pigeon River	Variable rocks. Shales used locally for granular aggregates.
	Huronian Supergroup	Gowganda Formation	Conglomerate, quartzite, arkose, greywacke	South of Batchawana Bay	Variable rocks. Rare occurrence in study area
Archean Superior Province		Igneous Intrusions	Granite, and related rocks	South of Goulais Bay, Batchawana Bay, Lake Superior and Pukaskwa Parks, west of Port Coldwell, north shore of Thunder Bay.	Fair to excellent aggregate potential. Potentially reactive in concrete.
		Greenstone Belts	Basalt, rhyolite, conglomerate, sandstone, mudstone	Wawa, Marathon, Schreiber areas, north shore of Thunder Bay.	Variable rocks.

A bedrock geology map indicating the general location of bedrock units in the study area is included as Figure 2-1.

2.2 BEDROCK GEOLOGY

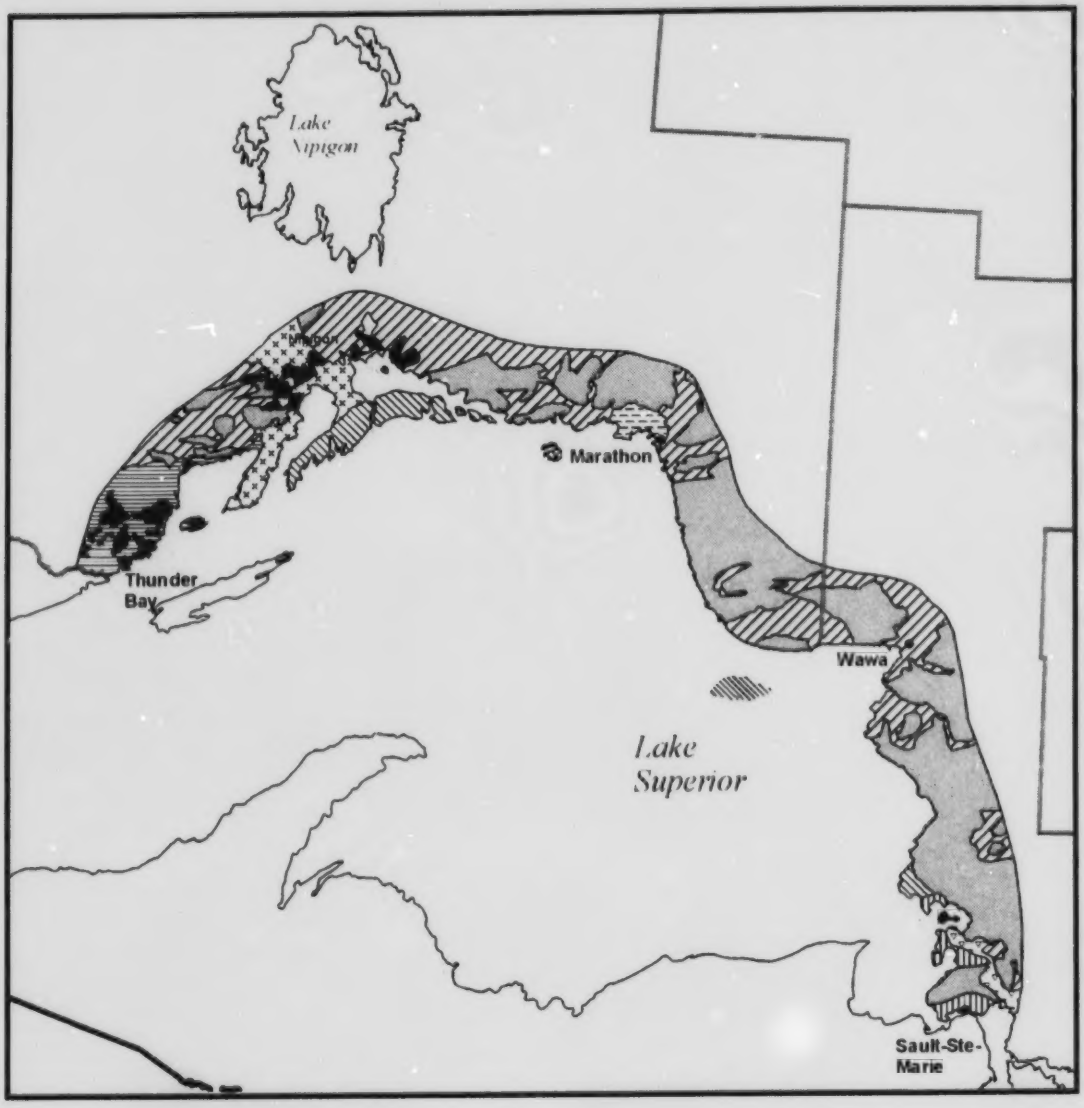
The Superior Province is the largest Archean craton in the world and extends from northeastern Quebec to the Dakotas. It is a complex region comprised of several east-trending subprovinces distinguished by compositional and structural characteristics and separated by faults. In the study area, the rocks of the Superior Province fall into 2 basic types – igneous intrusions and greenstone belts (Table 2-1). The igneous intrusions are comprised of massive to migmatitic granitoid rocks, which occur in large batholiths, plutons, or granitoid complexes that have been variably metamorphosed. These rocks occur near Sault Ste. Marie, Wawa, Terrace Bay and Thunder Bay. The greenstone belts are a sequence of volcanic and sedimentary rocks that have experienced low-grade regional metamorphism and have been intensely deformed and folded. The greenstone units are highly variable and may be soft or weak as a result of shearing and alteration. These rocks occur in the Wawa, Marathon and Schreiber areas, and along the north shore of Thunder Bay.

The Southern Province is a complex assemblage of sedimentary and volcanic rocks, of which several subunits occur in the study area. The oldest rocks in the Southern Province are sedimentary sequences deposited during a period of prolonged erosion that occurred between early to middle Proterozoic time. In the study area, these include sedimentary sequences of: 1) the Huronian Supergroup; 2) the Animikie Group; and 3) the Sibley Group. These sedimentary sequences include soft argillaceous materials, carbonate rocks, sandstones and conglomerates. Occurrences are provided in Table 2-1.

A significant portion of the rocks in the Southern Province formed as a result of an extensive crustal rift that developed in the Lake Superior basin in the middle Proterozic, approximately 1.1 billion years ago (Thurston 1991b). Vast quantities of magma were released during rifting, which flowed onto the surface of the adjacent plain or was injected into the country rock. Magma was also emplaced in deep-seated structures, such as the Trans-Superior Tectonic Zone and the Kapuskasing Structural Zone, where unique intrusive bodies were formed. The time of rifting is referred to as the Keweenawan and the rocks that were deposited are collectively referred to as the Keweenawan Supergroup.

The Keweenawan Supergroup is a succession of mafic to felsic volcanic rocks overlain by a sequence of sandstones, conglomerates and shales. In addition, a group of diabase rocks formed when mafic magma from the rift was forced into the adjacent country rock. In the study area, diabase intrusions occur as near vertical dikes that cut across the structure of pre-existing rocks, or as sills emplaced parallel to bedding planes of sedimentary rocks.

The dikes mainly occur in swarms which are identified from east to west as the Pukaskwa, Nipigon and Pigeon River swarms. The Pukaskwa dike swarm, located between Batchawana Bay and Marathon, is a series of narrow dikes that strike northwesterly with a near-vertical dip. The Nipigon dike swarm trends northerly, east of Lake Nipigon, and is a complex group of narrow dikes. The Pigeon River dikes occur south of the city of Thunder Bay, strike northwesterly, and dip steeply to the southeast. These dikes may be up to 40 km long and more than 100 m wide.



LEGEND (See Table 2-1 for descriptions)

Proterozoic Units

- Huronian Supergroup
- Animikie Group
- Sibley Group
- Port Coldwell Alkalic Complex
- Osler Group and Mamainse Point Formation
- Keweenawan Mafic Intrusions
- Oronto and Jacobsville Groups

Archean Units

- Greenstone Belts
- Igneous Intrusions

N

25 0 100 km

Scale 1:2,500,000

SOURCE:
Bedrock Geology of Ontario, Ministry of Northern Development and Mines, Map 2543 (East - Central Sheet) and Map 2542 (West - Central Sheet), 1991.

Figure 2-1: Bedrock Geology of the Study Area

There are 2 groups of diabase sills in the study area, the Logan and Nipigon sills, which occur between the Nipigon area and the international border south of Thunder Bay. The Logan diabase sills formed when mafic magma was injected between layers of the Animikie Group sedimentary rocks in the Thunder Bay area. Six major sills are present, each up to approximately 45 m thick. The sills provide an erosion-resistant cap over the softer sedimentary rocks forming the characteristic "mesa" geomorphology of the region. The diabase sills have columnar jointing which has resulted in the formation of many near-vertical escarpments that are at the flanks of the mesas. Blocks of diabase have detached from the escarpment face to form talus slopes at the base of many of the mesas.

The Nipigon diabase sills were formed in a similar way as the Logan sills, but are intruded into the Sibley Group sedimentary rocks east of the Sibley Peninsula. Like the Logan sills, the Nipigon sills form resistant caps over softer sedimentary rocks. The dominant diabase sill in the Nipigon area is 150 to 200 m thick and is locally capped by the erosional remnants of another sill believed to have had a similar thickness. In the study area diabase sills are exposed near Red Rock, on several of the islands in Nipigon Bay and on the mainland adjacent to the Nipigon River and Kama Bay.

In addition to the Keweenawan Supergroup and associated dikes and sills, the opening of the midcontinent rift caused some distinct igneous intrusions to develop in the study area. These include the Pine River-Mount Mollie Gabbro southwest of Thunder Bay, the Moss Lake Intrusion on Black Bay Peninsula, the St. Ignace Island Ring Complex and the Port Coldwell Alkalic Complex near Marathon.

The Pine River-Mount Mollie Gabbro is a composite, northeast-trending dike, 60 to 350 m wide, which extends 35 km from Crooks Township to McKellar Island in Lake Superior (Sutcliffe 1991). The dike is zoned, with its composition ranging from gabbro to granite.

The Moss Lake Intrusion (McIlwaine and Wallace 1976) and the St. Ignace Island Ring Complex (Giguere 1975) are circular-shaped, zoned structures that contain a central quartz-feldspar porphyry core with an outer rim of gabbro to anorthosite. It is believed that these structures are the remnants of conduits which conveyed magma to form the Nipigon sills.

The Port Coldwell Alkalic Complex is a composite three-ring structure that occupies an area of approximately 580 km^2 near Marathon (Puskas 1967; Walker et al. 1993). The ring structures become younger in a southwest direction along the Trans Superior Tectonic Zone. The 2 oldest rings have an outer rim of gabbro and an inner core composed of syenite. The youngest ring, centered on Pic Island in Lake Superior, consists of curved sheets of various types of syenite.

2.3 SURFICIAL GEOLOGY

A detailed assessment of surficial deposits in the study area is beyond the scope of this report. However, a brief overview of the regional surficial geology is provided below. Surficial deposits in the study area are unconsolidated glacial deposits containing gravel, sand, silt and clay in varying proportions. Sand and gravel deposits that are suitable for crushing are important resources of high quality aggregates. As such resources become diminished, bedrock aggregate resources will take on a greater significance.

Most of the surficial deposits in the study area were formed in the Quaternary Period (1.8 million years ago to present) in response to the repeated advances and retreats of glaciers across the region. Ontario was entirely covered by glacial ice, for the last time, approximately 20 000 years ago. It was not unit approximately 8000 years ago that all of the ice had melted from the province.

The glacial activity significantly modified Ontario's landscape and created many distinct topographical features. During glacial advance the land surface was scoured and large quantities of debris entrained by the glaciers was deposited beneath or at the margins of the ice. The powerful abrasive action of the glaciers is recorded throughout the study area by the numerous grooved, fluted and smoothed bedrock outcrops that are present.

Debris that was deposited at the ice margins is generally a poorly sorted, heterogenous mixture of sand, silt and clay with pebbles, cobbles and boulders. This material, called glacial till, occurs in the study area as discontinuous, flat sheets of low topographic relief (ground moraines) or as thicker, irregular deposits at the limits of ice movement (end moraines). While parts of the moraines may contain good crushable aggregate resources, the deposits are highly variable and often contain high proportions of silt and clay which limits their use for aggregates.

During deglaciation large volumes of meltwater were released from the glaciers. Where the meltwater flowed in channels or in broader sheets important deposits of well sorted and washed sand and gravel were formed. However, such deposits are not common along the shore of Lake Superior which was inundated by a succession of proglacial lakes that formed along the margin of the Superior basin. The lake bottoms were sites of deposition of fine grained sediments where thick and expansive plains of laminated silt and clay were formed. Significant deposits of this nature occur between the Nipigon and the Sibley Peninsula, in Crooks and Pardee Townships south of Thunder Bay and also areas southeast of Marathon and around Sault Ste. Marie. Where glaciofluvial channels entered the glacial lakes deltas were formed. Glaciolacustrine delta deposits in the study area generally range from silt to fine sand and tend to have a low content of crushable material. Examples include the large Kaministiquia delta south of Thunder Bay and several deltas in the Sault Ste. Marie area.

At the shores of the glacial lakes, waves and currents concentrated sand and gravel in beaches, spits and bars. Flat, stepped terraces and abandoned beaches with rounded cobbles, gravel and sand are common in the study area in such places as Wawa, Marathon, Terrace Bay, Nipigon and Thunder Bay. In Sault Ste. Marie, wave action and subsiding lake levels reworked some of the deltaic deposits at the flanks of the Gros Cap Highland into a series of beach terraces that are a primary aggregate resource in this area (Ontario Geological Survey 1985b).

In summary, surficial deposits in the study area are dominated by glacial till deposits and glaciolacustrine silt and clay deposits which are generally unsuitable for aggregate use. Deposits containing coarse aggregates suitable for crushing mainly occur in reworked beaches and some of the glaciolacustrine deltas. Glaciofluvial and moraine deposits occurring inland from the study area are also important sources of high quality crushable aggregate for the region.

2.4 AGGREGATE POTENTIAL OF BEDROCK UNITS

The aggregate potential of bedrock units across the study area is variable and depends on the physical and chemical characteristics of the rock. Metamorphosed volcanic and sedimentary rocks in the greenstone units are generally inconsistent, exhibit planar weaknesses or significant alteration and are considered to have limited potential for high quality aggregate use. Similarly, sedimentary sequences in the Huronian Supergroup, Animikie Group and Sibley Group have low potential because they contain soft, argillaceous rocks which are generally unsuitable for use in asphalt or concrete. Some of the sandstones of the Keweenawan Supergroup have been used for building stone in the past but their durability for aggregate use is expected to be poor. Their occurrence in the study area is also relatively rare and they are confined to narrow, discontinuous belts in a few localities. Other rock types in the study area considered to have low aggregate potential are the highly variable Mamainse Point Formation and most members of the Osler Group.

Rocks in the study area that have good potential to produce quality aggregates generally fall into one of 2 groups – Archean intrusions (granites) and Keweenawan intrusions (diabases). The granites are hard, durable and relatively homogeneous and appear to be suitable for a variety of aggregate uses. They are composed mainly of quartz and feldspar, with subordinate amounts of "dark" minerals which are commonly hornblende or biotite. Such minerals have characteristically smooth crystal faces, and physical or chemical treatments of derived aggregates may be necessary to prevent adhesion problems in asphalt and concrete mixtures. In addition, granitic rocks contain silica, which may react with cement and lead to concrete deterioration. These factors need to be assessed on a site by site basis prior to aggregate resource development.

Diabase is a medium-grained basic igneous rock composed mainly of plagioclose and pyroxene, with subordinate amounts of olivine, iron-titanium oxides and chloride. Silica content in diabases is relatively low compared to granites. Because of its excellent physical qualities, such as durability, uniformity and density, diabase is gaining recognition in Ontario as an important source of high quality aggregate. Potential uses of diabase include concrete and asphalt stone, high quality railway ballast and armour stone.

In addition to the granites and diabases there are a few unique intrusions in the study area that have marginal to fair potential to produce quality aggregates. These were mentioned previously (Section 2.2) and include the Pine River-Mount Mollie Gabbro, the Moss Lake Intrusion, the St. Ignace Island Ring Complex and the Port Coldwell Alkalic Complex.

The first 2 intrusions contain gabbro which is a rock with similar properties as diabase. The St. Ignace Island Ring Complex is a variable group of rocks that generally appear to be susceptible to weathering. However, based on field inspections, some of the rocks are relatively uniform and durable and it is possible that good quality aggregate sources could be found within the body. A negative aspect for resource development is that St. Ignace Island is remote.

The Port Coldwell Alkalic Complex is a large, accessible intrusive body that is mainly composed to syenite. Syenite is a coarse-grained igneous rock that is similar to granite but has a higher alkali feldspar content and lower quartz content. Several peculiar types of syenite are present in the Port Coldwell Alkalic Complex including nepheline syenite, pyroxene syenite, amphibole syenite and quartz syenite (the distinguishing mineral being included as the first word of the name). Some of the syenites in the complex have a distinct appearance due to the unique

play of light reflected from crystals in the rock. The syenites range in colour from brick red to chocolate brown to grey. Many of the exposed rock faces exhibit a rusty to dark brown colour.

The potential of rocks in the Port Coldwell Alkalic Complex to produce aggregates is variable and mainly depends on the effects of weathering and alteration. While some of the rocks are quite uniform, hard and consistent, others have a dull, weathered, sometimes crumbly-looking appearance. Some of the rocks are exceedingly coarse-grained and tend to break with an undesirable smooth cleavage. The nepheline syenites in the Mink Harbour-Port Coldwell area appear to be the most uniform and durable rocks within the Complex and have the greatest potential to produce aggregates of high quality.

A detailed discussion of the aggregate potential of selected candidate resource areas, based on field observations and laboratory test results, is provided in Section 3.2.

3.0 Candidate Resource Areas

3.1 CANDIDATE RESOURCE AREA SELECTION

Igneous and metamorphic rocks, such as those found in the Lake Superior area, have been used sparingly for the manufacture of aggregates in Ontario to this point in time. The reason for this situation is that substantial resources of high quality natural sand and gravel exist in the region. These resources have proven satisfactory for meeting local needs and they have the advantage of requiring a simpler, less expensive, extraction and manufacturing process compared to quarrying of rock sources. In the last few years 2 factors have encouraged interest in the igneous and metamorphic rocks of the Canadian Shield:

- traditional sand and gravel sources are becoming depleted
- there is an increasing interest in using very high quality and consistent aggregate products to improve performance and life expectancy, particularly in concrete and asphalt applications.

The Ontario Ministry of Transportation has recently conducted a significant amount of testing of these rock types and there have been a number of commercial aggregate operations established in these rocks in the last few years.

Recent experience with igneous and metamorphic rocks has confirmed that a variety of rock units are capable of meeting the basic test requirements for aggregate materials as specified in Special Provisions 110F11, 110F12 and 110F13 published by the Ministry of Transportation. For igneous or metamorphic rocks to be used as an aggregate source they must exhibit a high degree of uniformity and predictability in addition to being sound both physically and chemically. Geological studies and related test data have confirmed that larger igneous intrusions are an excellent target for exploration for aggregate resources. Many intrusions are uniform and consistent, are of significant size and are generally well known from existing bedrock mapping. Metamorphic rocks may also meet high test specifications and

may prove to be consistent, but these rocks may vary mineralogically and significant testing will be required in order to demonstrate consistency.

The current study was designed to give an overview of the aggregate resource potential of the rocks along approximately 800 km of Lake Superior shoreline. The focus of the study was to target those rock units most likely to yield high quality rock and containing volumes capable of supporting a large scale commercial operation. Thus, a decision was made to target intrusive bodies which contained potentially durable and uniform rocks, based on a review of available regional scale mapping and later on a review of available detailed mapping.

Original identification of the candidate rock units was completed at a scale of 1:250 000 based on descriptions of rock types from the Geology of Ontario bedrock map series (Ontario Geological Survey 1991b, 1991c). Areas containing sedimentary rocks, heavily altered or mineralized rocks and heavily metamorphosed rocks were removed from consideration at this level of analyses. Remaining intrusive bodies were assessed for their geological characteristics using available detailed geological mapping.

Candidate Resource Areas were selected prior to the field evaluation based on a number of factors. These included rock type and textural features, geological setting and structure, deposit size and location within 5 km of the Lake Superior shoreline. Overburden thickness was not a significant factor, as the majority of the Lake Superior shoreline consists of exposed bedrock or shallow drift over rock.

Only bedrock units with potential to produce high quality aggregates for use in asphalt and concrete applications were considered in the study. Several rock types in the study area are not capable of meeting these requirements and were excluded from detailed field assessments. These rocks may be suitable for other uses such as granular aggregates or specialty stone products.

Existing geological mapping and government land use information (e.g., parks) was used to identify 15 Candidate Resource Areas within the study area (Figure 3-1). Although dictated primarily by geological controls, locations were selected to provide representative coverage of the entire study area from Sault Ste. Marie to the international border at Pigeon River.

3.2 DISCUSSION OF CANDIDATE RESOURCE AREAS

3.2.1 Candidate Resource Area 1

Candidate Resource Area 1 is located northwest of Sault Ste. Marie and north of Highway 550 (Figure 3-2). It is in the Gros Cap Highland which is part of the Ramsey-Algoma Granitoid Complex of the western Abitibi Subprovince (Jackson and Fyon 1991). The Ramsey-Algoma Granitoid Complex is a large igneous intrusion between Sault Ste. Marie and Sudbury that consists of 3 regions of gneissic rocks and one region of granitic rocks.

The candidate source rock in area 1 is medium-grained diorite to granodiorite with massive to foliated texture defined by elongated crystals of hornblende, pyroxene or mica. Related rocks include gneissic-textured granitic rocks in the north part of the candidate area and a few relatively small diabase dikes.

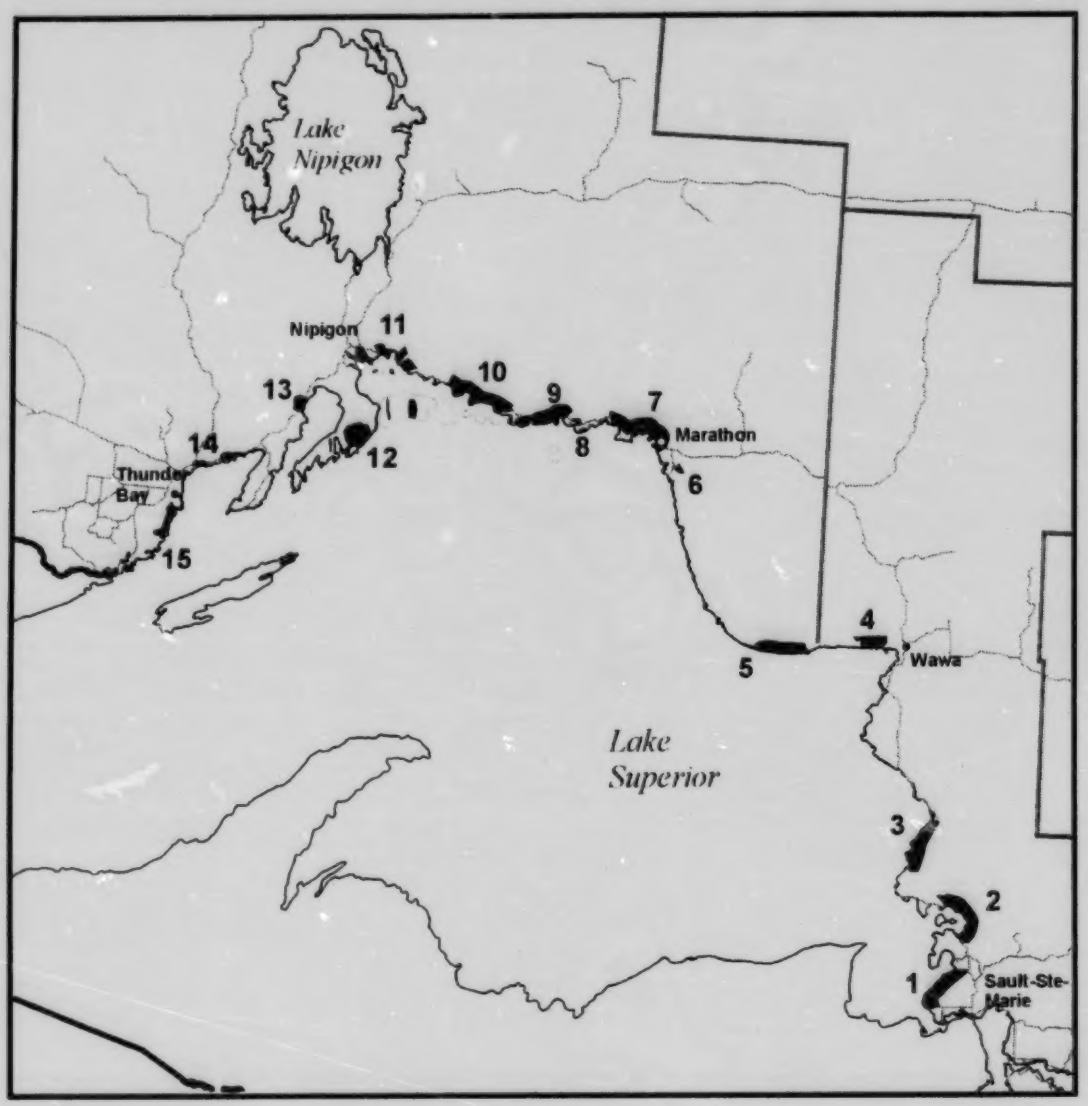


Figure 3-1: Candidate Resource Area Location Map

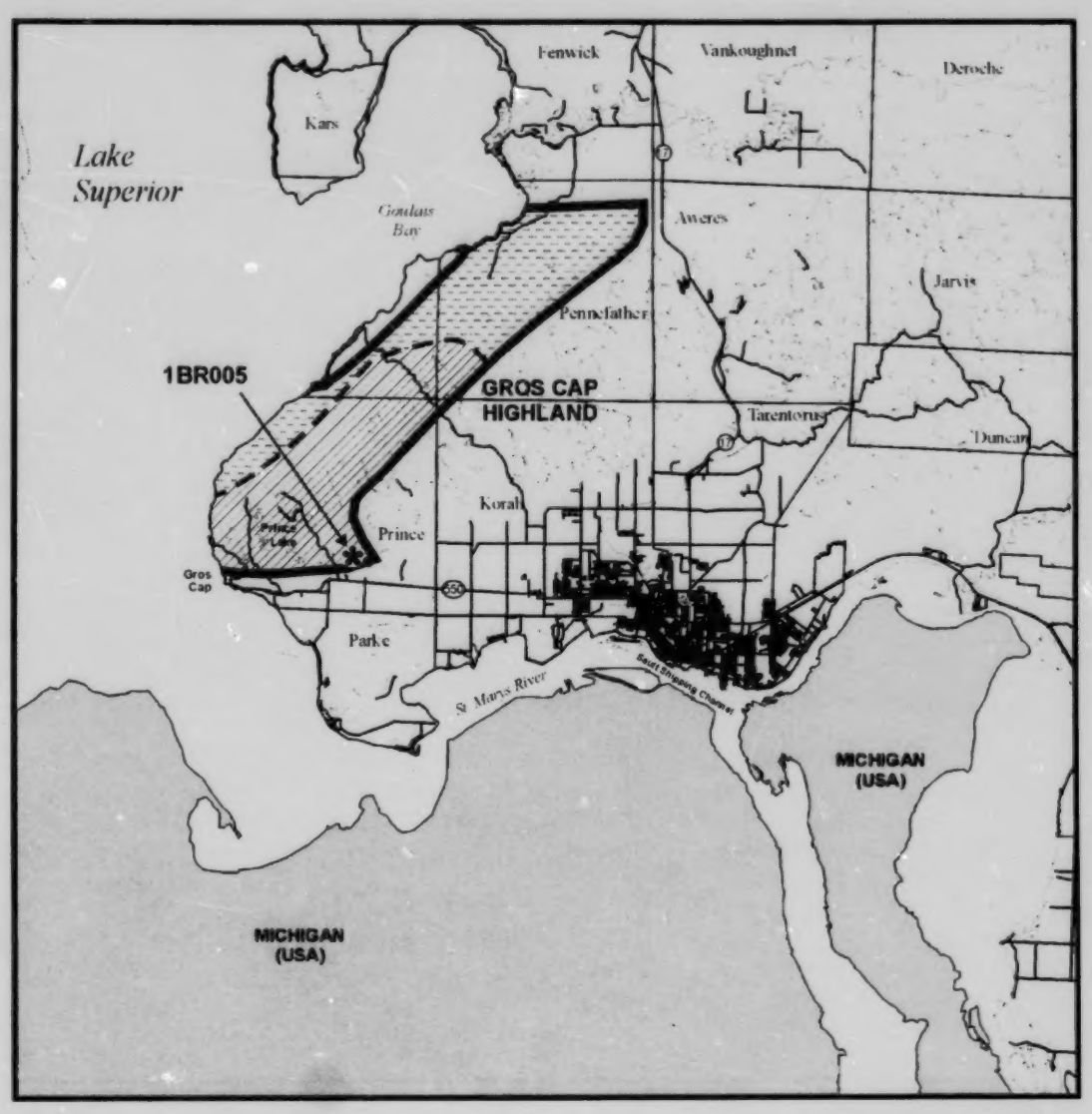


Figure 3-2: Candidate Resource Area 1

Large resource volumes are potentially available in area 1. The Gros Cap Highland rises sharply above the sedimentary bedrock terrain to the south. Some of the sheer rock faces on the north side of Highway 550 reach approximately 100 m in height.

Area 1 is close to existing shipping facilities in Sault Ste. Marie. Processing and shipping of aggregates was carried out at downtown facilities in the late 1980s. It is possible that new shipping facilities could be developed on Goulais Bay which is closer to the resource. It is noted that most of the undeveloped shoreline properties in Prince and Dennis townships are now under private ownership.

Sample 1BR005 was a diorite sample collected from an old quarry site located on the north side of Highway 550, approximately 1 km east of Prince Lake Road. The aggregate test results are summarized in Table 3-1, and indicate that the sample rock is potentially capable of satisfying Ontario specifications for HL1 asphalt and concrete stone, and American equivalents. Based on field information, the massive, uniformly textured intrusive rocks in the Gros Cap Highland have a high potential for the manufacture of high quality aggregates. Sedimentary rocks along the lakeshore should be avoided for high quality aggregate use.

3.2.2 Candidate Resource Area 2

Candidate Resource Area 2 is located along the east shore of Batchawana Bay between Havilland on Highway 17 and Fisher Township (Figure 3-3). Like area 1, it is part of the Ramsey-Algoma Granitoid Complex of the western Abitibi Subprovince. The candidate source rock is massive to weakly foliated granite to granodiorite.

Large resource volumes are potentially available in area 2. The terrain is rugged and inland parts of the candidate area rise more than 250 m above lake level.

Area 2 is located approximately 75 km by water from existing shipping facilities in Sault Ste. Marie. There are several locations along the protected coastline of Batchawana Bay where new docking facilities might be developed, however, hydrographic charts (Canadian Hydrographic Service 1998) indicate that water depths north and south of Batchawana Island are shallow. There are also numerous residential properties along the shore of the bay.

Based on available property assessment rolls, lands east of Highway 17 are used mainly for commercial lumbering. A licensed sand and gravel pit exists just east of the highway, 1 km north of Jones Landing. This site has access to granite bedrock suggesting there may be opportunities for future bedrock extraction.

Sample 2BR014 was collected from a highway cut in massive granite approximately 2 km north of Jones Landing. The aggregate test results are summarized in Table 3-1 and indicate that the sample rock is potentially capable of satisfying Ontario specifications for HL1 asphalt and concrete stone and American equivalents. Most of the rock in the candidate area has potential to produce high quality aggregates, except for isolated areas of sedimentary rocks located near Harmony Bay.

TABLE 3-1: AGGREGATE TEST RESULTS
PHYSICAL EVALUATION AND ASSESSMENT OF BEDROCK AGGREGATE POTENTIAL
NORTH SHORE OF LAKE SUPERIOR

Candidate Resource Area	Field Sample Number	Laboratory Sample Number	Rock Type	PN Granular	PN Hot Mix & Concrete	MDA Loss, Coarse (%)	MDA Loss, Fine (%)	MgSO4 Loss (%)	Freeze-Thaw Loss (%)	LAA Loss (%)	Absn. (%)	Bulk Relative Density	AMB Expansion (%)
1	1BR005	16312	Diorite	100	100	7.5	10.6	1.4	0.9	16	0.45	2.753	0.101
2	2BR014	16313	Granite	100	101	7.2	8.6	1.2	1.5	18	0.43	2.687	0.037
3	3BR018	16314	Granite	100	101	7.5	10.3	1.6	1.8	20	0.38	2.627	0.058
4	4BR084	16371	Granite	100	101	8.1	10.8	0.8	0.6	18	0.46	2.703	0.078
5	5BR078	16315	Diorite	101	103	8.2	13.3	1.1	1.5	16	0.40	2.828	0.073
5	5BR081	16372	Granite	100	101	8.4	8.9	1.0	0.8	25	0.49	2.666	0.026
7	7BR026	16316	Syenite	100	105	7.7	10.2	2.9	1.8	31	0.54	2.785	0.019
7	7BR030	16317	Syenite	100	102	6.8	9.7	2.1	1.0	20	0.37	2.665	0.015
9	9BR042	16318	Granite	100	102	9.7	10.1	2.4	0.9	28	0.46	2.666	0.037
10	10B043	16319	Granite	100	103	9.4	9.1	2.2	1.1	24	0.47	2.682	0.032
10	10B051	16320	Granite	100	100	7.2	8.8	1.5	1.7	22	0.39	2.624	0.056
11	11B053	16321	Diabase	100	101	6.5	11.5	2.1	2.1	15	0.44	3.017	0.047
12	12B071	16322	Gabbro	100	102	8.8	12.0	3.9	3.3	19	1.23	2.849	0.069
12	12B072	16323	Diabase	100	100	6.9	11.3	3.1	2.6	18	1.24	2.841	0.12
12	12B073a	16324	Rhyolite	100	102	6.7	8.5	3.5	1.5	18	0.76	2.685	0.257
12	12B073b	16325	Anorthosite	100	101	9.7	10.0	3.1	1.3	22	1.01	2.763	0.144
13	13B061	16326	Diabase	100	102	7.6	10.7	2.5	1.7	15	0.34	3.028	0.064
14	14B064	16327	Granite	100	100	8.9	8.8	1.5	1.1	27	0.32	2.65	0.048
15	15B069	16328	Diabase	100	101	8.5	12.2	2.6	4.5	18	0.65	2.968	0.08

PN Petrographic Number
MDA Micro-Deval Abrasion
MgS04 Magnesium Sulphate Soundness
LAA Los Angeles Abrasion
Absn. Absorption
AMB Accelerated Mortar Bar

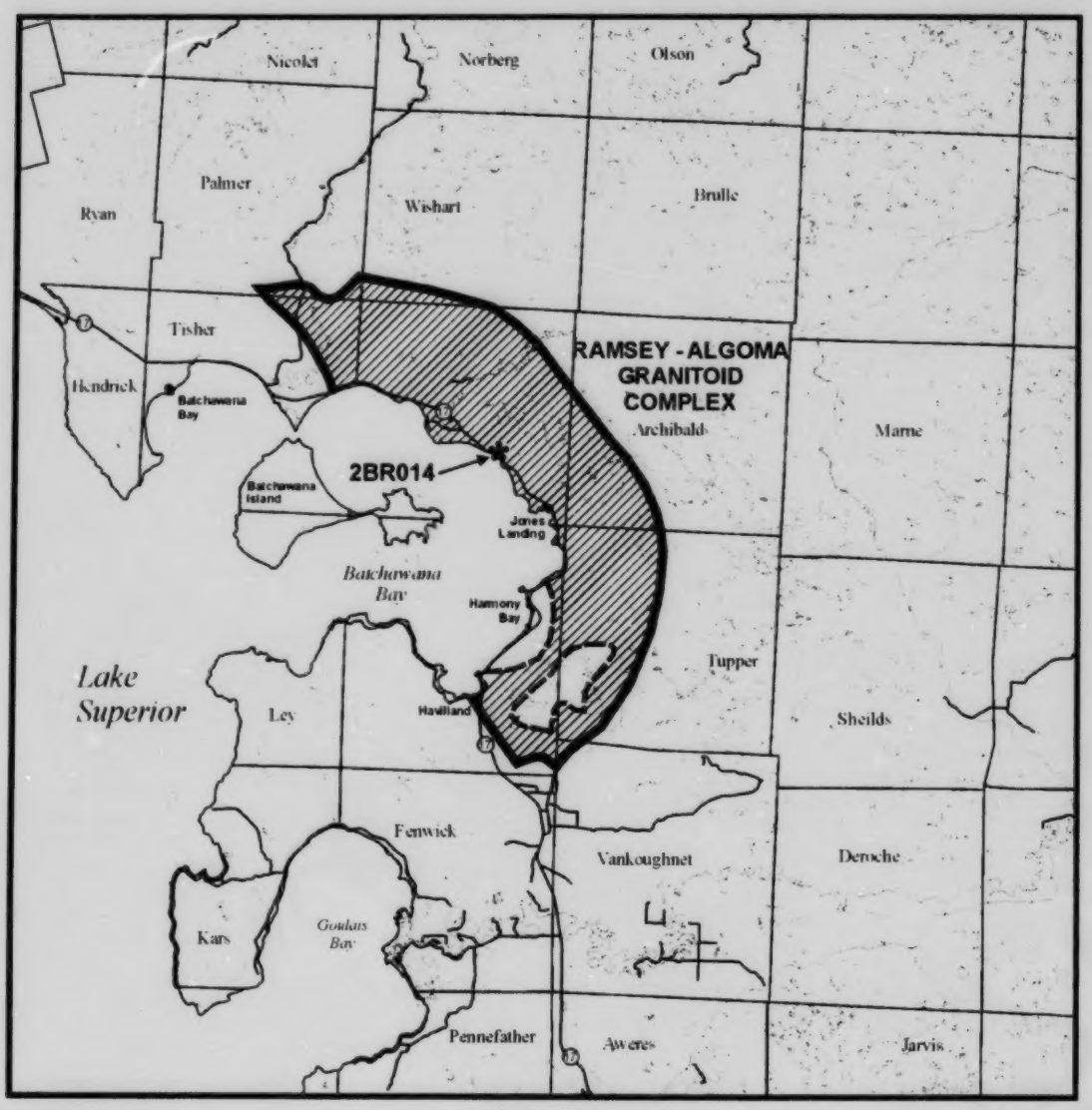


Figure 3-3: Candidate Resource Area 2

3.2.3 Candidate Resource Area 3

Candidate Resource Area 3 lies between Mica Bay and the southern limit of Lake Superior Provincial Park (Figure 3-4). It is located in the gneiss terrane of the Wawa Subprovince (Williams et al. 1991). The southern part of area 3 is characterized by massive to foliated granitic rocks intruded by a number of mafic to intermediate rocks with gneissic textured rocks occurring in the north.

The aggregate potential of area 3 is lower than first anticipated due to the variability observed in many of the outcrops. Outcrop inspections have revealed that the bedrock is often highly contorted and migmatitic in character and zones of relatively soft mafic material may be present within the granitic matrix. Consistent and durable rock does exist at a few locations, but any development of aggregate resources in this area should be highly selective.

Area 3 is located approximately 100 km north of existing shipping facilities at Sault Ste. Marie. Opportunities to develop new facilities may exist in the Alona Bay area or off Pointe aux Mines and Theano Point. This shoreline is rugged with approximately 75 to 150 m of relief above the lake. It is noted that an existing shipping dock exists at Michipicoten Harbour, north of Lake Superior Provincial Park and approximately 10 km southwest of Wawa.

Based on current information, area 3 is a mixture of Crown and privately owned land with large tracts designated for commercial lumbering. Large areas of Crown land exist south of Pointe aux Mines and south of Montreal River. Private cottages exist along the shore at Metheany Creek and there are commercial resorts at Montreal River Harbour.

A sample of the most uniform and massive-looking granitic rock observed in the candidate area was collected from a fresh highway cut east of Pointe aux Mines. The aggregate test results for sample 3BR018 are summarized in Table 3-1. The test results indicate that the sample rock is potentially suitable for high quality asphalt and concrete stone. Quality potential is expected to decline with increasing metamorphism and variability. These factors will pose challenges in finding high quality resources in area 3.

3.2.4 Candidate Resource Area 4

Candidate Resource Area 4 is located approximately 20 km west of Wawa between McCoy's Harbour and Minnekona Point on the north shore of Lake Superior (Figure 3-5). Presently there is no road access and the area is remote and undeveloped.

The candidate area is part of the southeastern arm of the Pukaskwa Batholith (Williams et al. 1991), a large Archean intrusive body mainly composed of foliated to gneissic tonalite (a rock similar to granite). Field inspections indicate that the candidate source rock is composed mainly of feldspar and quartz with trace amounts of hornblende and biotite mica. The texture is weakly foliated with a fairly uniform grain size. The rock is hard and durable and has the potential to produce high quality aggregate.

Area 4 has a rugged undeveloped coast with relatively gradual relief at the shore. The nearest existing shipping dock is at Michipicoten Harbour to the east. An aggregate producer is presently seeking approval to ship HL1 aggregate from a diabase quarry located just west of this dock. There may be opportunities to develop other docking facilities in one of the numerous coves

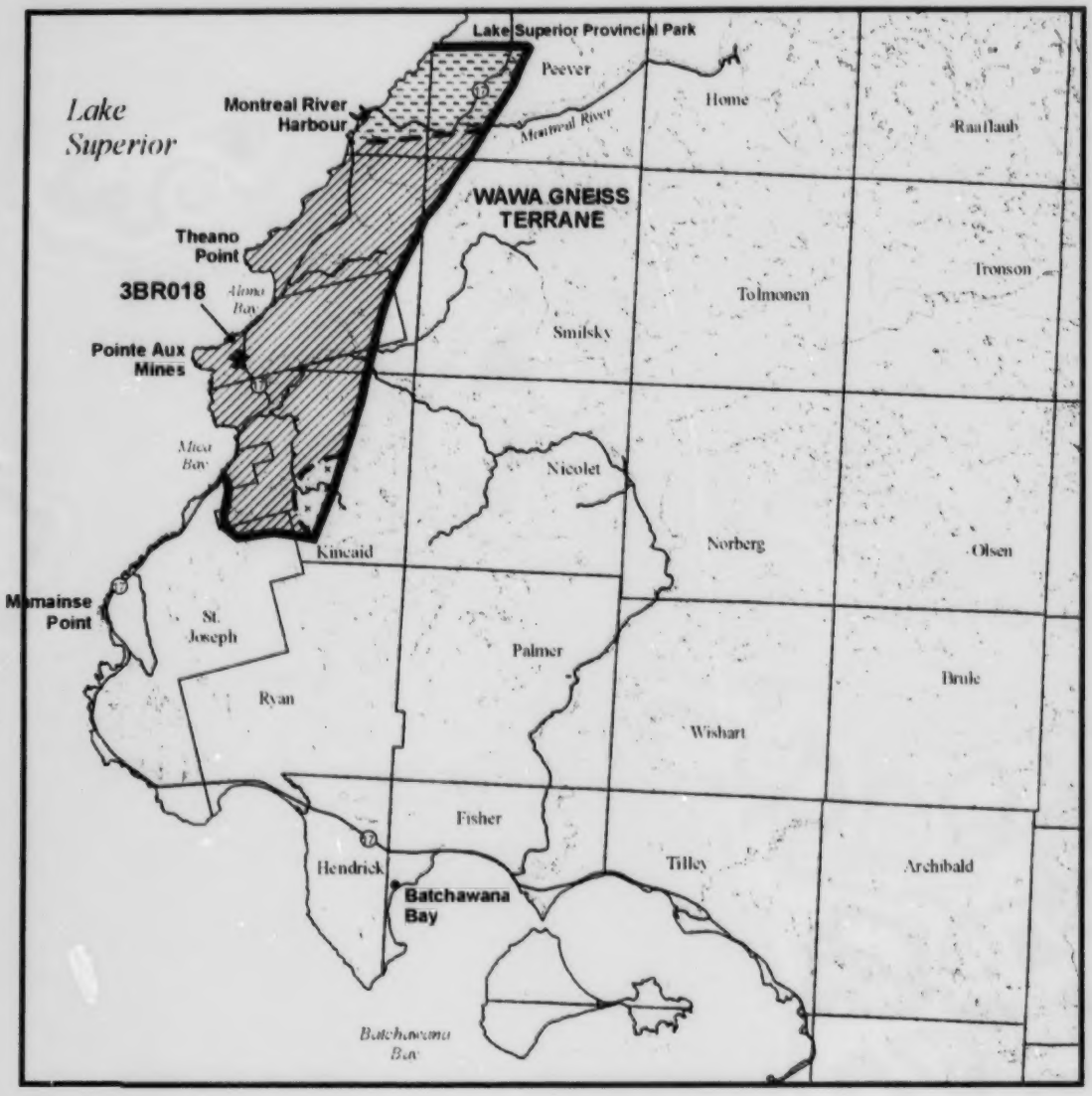


Figure 3-4: Candidate Resource Area 3

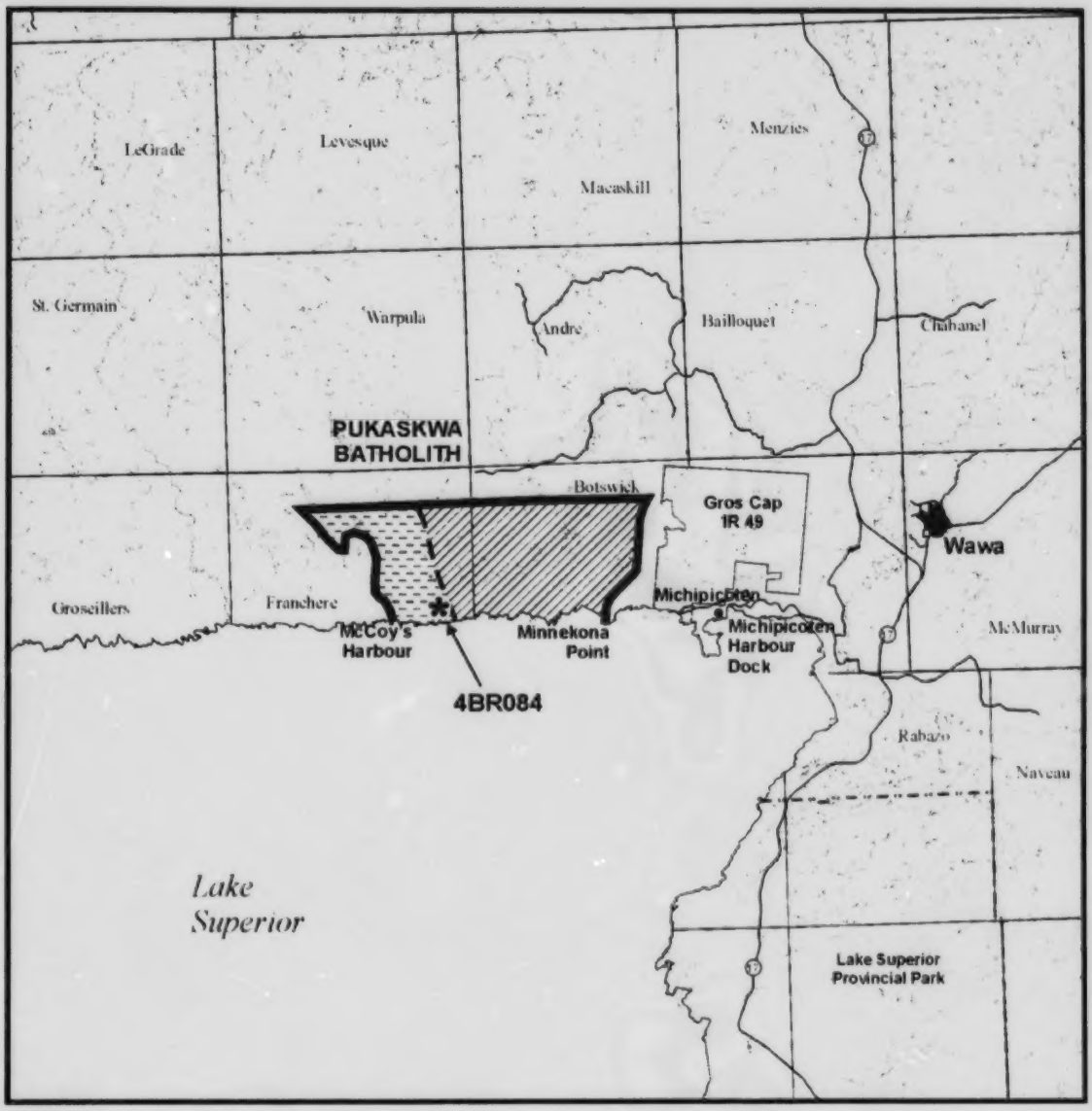


Figure 3-5: Candidate Resource Area 4

that exist along the coast in area 4 which would offer some protection from the notorious Lake Superior winds and waves.

Sample 4BR084 was collected from a shoreline outcrop at McCoy's Harbour. The aggregate test results are summarized in Table 3-1 and indicate that the sample rock has potential to satisfy Ontario specifications for HL1 asphalt and concrete stone, and American equivalents. Most rocks in area 4 have potential to produce high quality aggregates, except for some of the gneissic rocks with elevated mica content.

3.2.5 Candidate Resource Area 5

Candidate Resource Area 5 is approximately 50 km west of area 4 between Ganley Harbour and Point Isacor on Lake Superior (Figure 3-6). Presently there is no road access to the area and it is remote and undeveloped. Paint Lake Road, which exits Highway 17 and leads approximately 75 km south to the Eagle River Mine, terminates approximately 10 km north of the shoreline near the east boundary of the candidate area. The terrain between the mine site and the shore is rugged with intermittent bogs and dense bush.

The candidate area lies within the Floatingheart Batholith of the Wawa Subprovince (Williams et al. 1991), and it is similar to the Pukaskwa Batholith that outcrops in area 4. The Floatingheart Batholith is a moderately foliated to massive tonalite, composed of quart and feldspar with small amounts of biotite and hornblende. Field inspections indicate that the rock is rich in quartz and is medium-to coarse-grained with occasional quartz phenocrysts and mafic xenoliths. Quartz content varies locally, but overall the rock is fairly uniform. The rock is hard and durable and has potential to produce high quality aggregate.

In addition to the batholith, the area is intruded by numerous diabase dikes of the Pukaskwa dike swarm. The dikes strike northwesterly across the area and are easily distinguished in exposures by their dark colour cutting the light coloured tonalites. The dikes themselves are generally too narrow and intermittent to be significant aggregate resources, but they are not expected to effect the overall quality of the rock if the tonalite and diabase were mined together.

The coastline of area 5 is similar to that of area 4 and similar considerations for shipping will apply. Large resource volumes are potentially available.

Sample 5BR081 was collected from a shoreline outcrop at Le Petit Mort Rocks near the western limit of area 5. The aggregate test results are summarized in Table 3-1 and indicate that the sample rock has potential to satisfy Ontario specifications for HL1 asphalt and concrete stone, and American equivalents. The Floatingheart Batholith appears to be a large, uniform body and most parts of the candidate area are expected to have similar high potential to produce high quality aggregates.

The Eagle River gold mine is located in an intrusive body just north of the 5 km study area limit for area 5. The mine generates a fairly uniform diorite waste rock that may have potential aggregate applications. However, access to the mine site from the Lake Superior shore is very difficult due to the rugged topography. Aggregate test results for a sample of the mine waste rock, designated as 5BR078, are reported in Table 3-1 and indicate the rock has potential for high quality

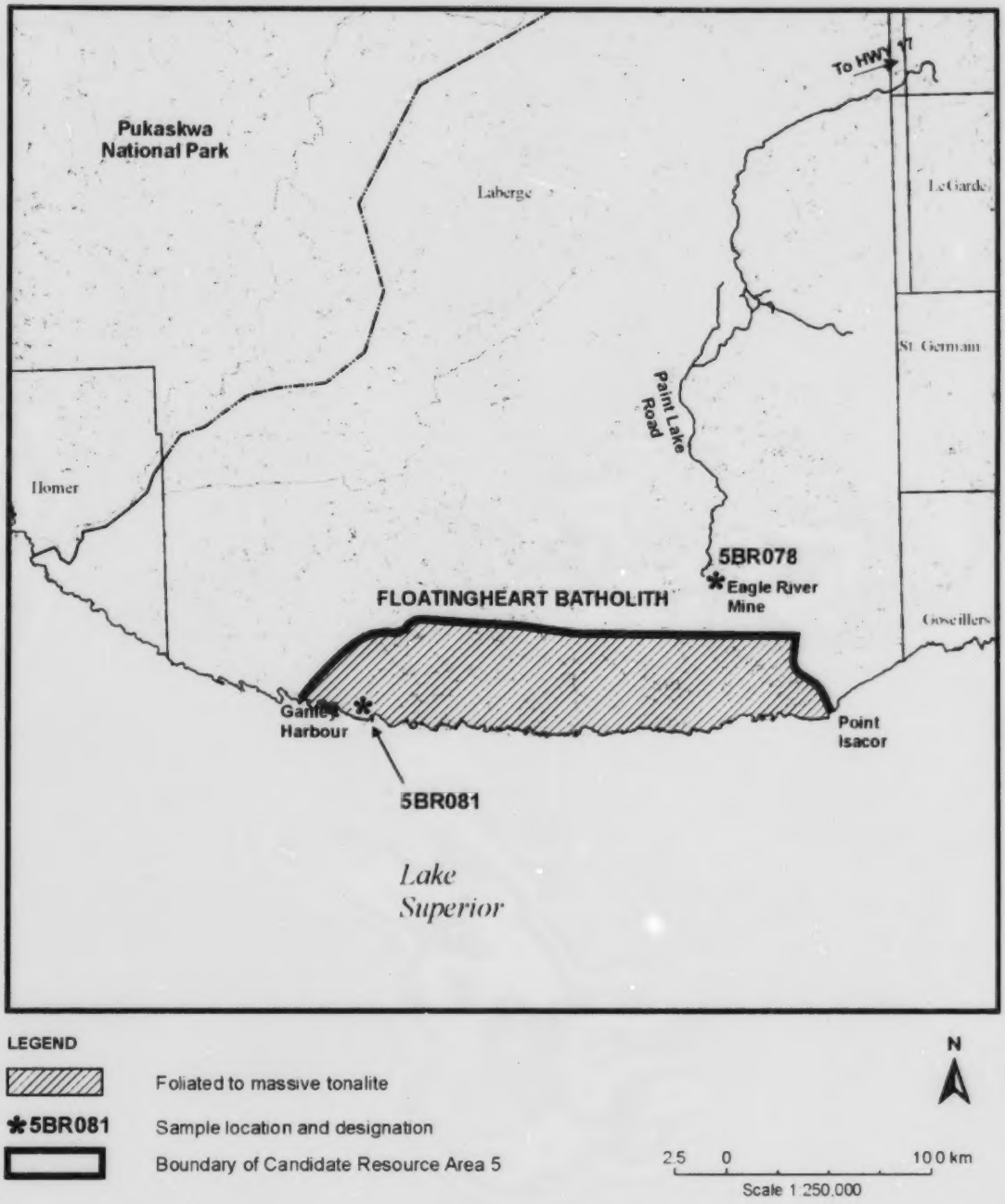


Figure 3-6: Candidate Resource Area 5

aggregate use. Sulphide content and general consistency of the waste rock should be considered if this potential resource is to be developed.

3.2.6 Candidate Resource Area 6

Candidate Resource Area 6 is a relatively small area between the northern limit of Pukaskwa National Park and the Pic River (Figure 3-7). Area 6 lies within the Heron Bay Pluton (Muir 1982), an elliptical-shaped intrusion of grandiorite centered between Rous Lake and Hattie Cove.

While the lithology of the intrusion may be favourable for producing quality aggregate, the development potential of Area 6 is constrained by proximity to Pukaskwa National Park and the Pic River First Nation Reservation. Bedrock exposure is relatively poor in the area and access to the Lake Superior shoreline for potential shipping transport is limited. A private commercial shipping dock operates at Heron Bay, approximately 5 km to the northwest. No samples from Area 6 were submitted for testing.

3.2.7 Candidate Resource Area 7

Candidate Resource Area 7 lies within the Port Coldwell Alkalic Complex between Peninsula Harbour at Marathon and McKellar Harbour west of Neys Provincial Park (Figure 3-8, back pocket). The Port Coldwell Alkalic Complex is a large igneous intrusion composed of gabbro and syenite. The aggregate potential of the rocks within the intrusion is variable and depends on rock texture, and the degree of alteration and weathering.

The massive gabbros in the intrusion are similar to diabase and have aggregate potential. However, these rocks only occur in relatively narrow zones within the candidate area. Some of the gabbros are layered and zoned contain sulfides or exhibit a pegmatitic character (Walker et al. 1993). These characteristics generally reduce aggregate quality potential of the gabbros.

Based on field inspections, the aggregate quality potential of the syenites within the intrusion ranges from poor to good. The grey nepheline syenites in the Coldwell-Mink Harbour area west of Marathon appear to have the greatest potential based on texture, hardness and uniformity. Selected exposures of pyroxene syenites (red to reddish-brown in colour) around Peninsula Harbour, and to the east along Highway 17, have favourable quality characteristics. Some of the syenites, however, are coarse-grained with a dull, weathered and sometimes crumbly-looking appearance. The visible character of the rock suggests durability concerns.

The terrain in area 7 is rugged and some of the local hills approach 250 m relief above lake level. Outside Marathon most of the candidate area is undeveloped. A large tract of land around Peninsula Harbour is owned by the local pulp mill and there are plans to develop tourist facilities.

In the late 1920s, varieties of syenite from the Peninsula Harbour area ("black granite" and "red granite") were quarried for commercial building stone. Blocks of the quarried rock were shipped by rail to construct buildings in Toronto, Detroit and Chicago. It is not known if the bedrock was used to produce aggregates.

The pulp mill at Marathon operates a small protected shipping dock on Peninsula Harbour. Favourable locations for developing new shipping facilities also may exist along the north shore of Peninsula Bay, including Port Munroe, Red Sucker Cove, Mink Harbour and Port Coldwell.

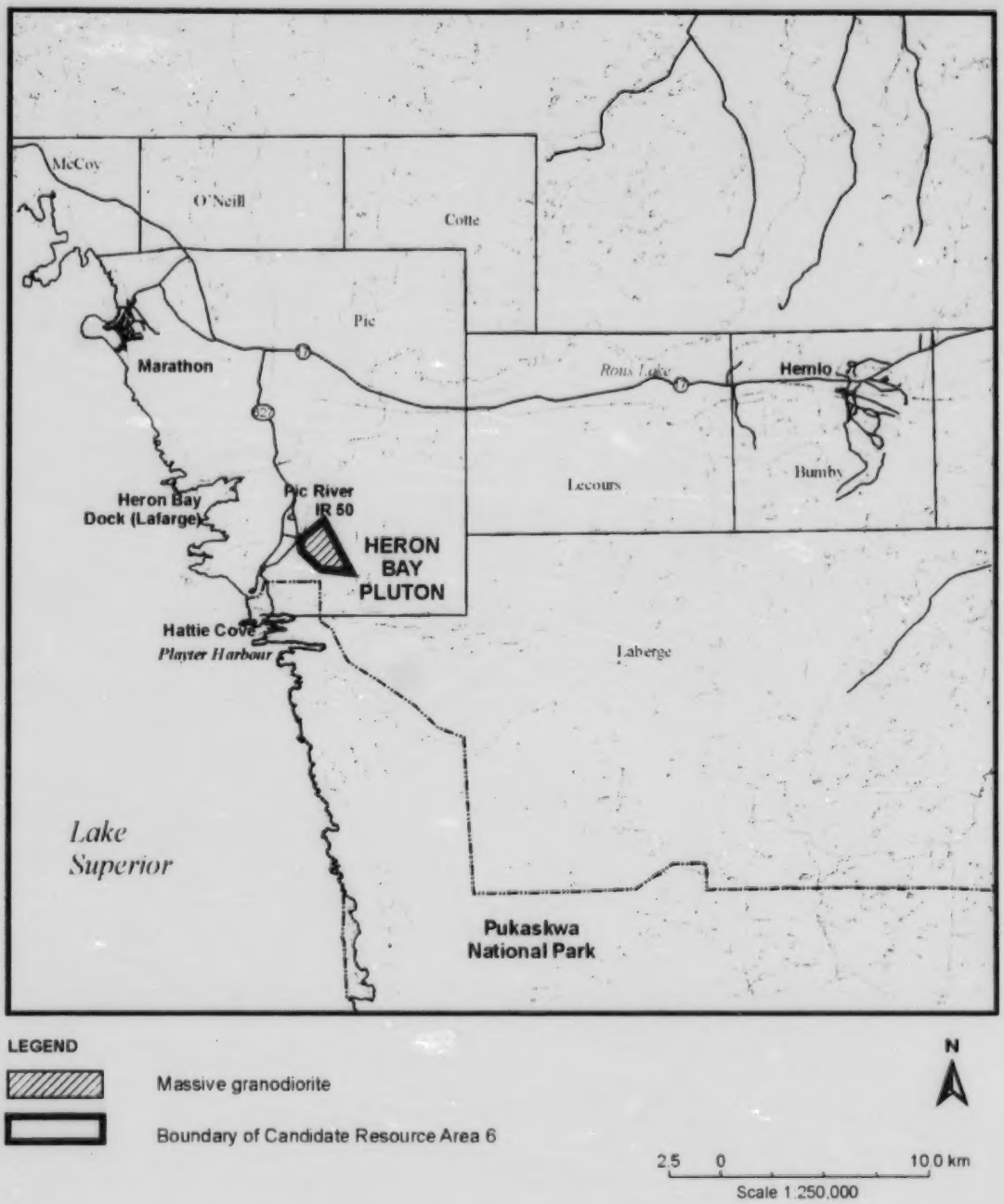


Figure 3-7: Candidate Resource Area 6

Two samples were collected from Highway 17 rock cuts to evaluate the aggregate quality potential in area 7. Sample 7BR026 was collected east of Port Munroe and sample 7BR030 was collected near the western municipal boundary of Marathon. The aggregate test results are summarized in Table 3-1. Both test results meet Ontario specifications for HL1 asphalt and concrete stone. However, it should be noted that the Port Coldwell complex contains a variety of rock types, some of which have reduced aggregate potential based on visual inspections. Exploration is required in area 7 to identify potential high quality resources. Exploration should be focussed on fresh, fine-to medium-grained units, particularly north of Peninsula Bay.

3.2.8 Candidate Resource Area 8

A group of mafic to ultramafic intrusions that occur in the Little Steel Lake area east of the Steel River are designated as Candidate Resource Area 8 (Figure 3-9). Based on regional geological mapping these rocks range from gabbro to anorthosite in composition. They intrude highly deformed and altered metasedimentary and metavolcanic rocks and are inferred to be part of the Archean supercrustal assembly of the Superior Province.

Parts of the mafic intrusions are exposed in rock cuts on Highway 17. Based on inspections of these outcrops the intrusions range in composition from fine-grained diabase containing pyroxene and plagioclase feldspar, to a medium-grained amphibolite-like rock containing plagioclase feldspar and slightly aligned, acicular hornblende laths up to approximately 5 mm long. Both rocks appear to be hard and durable, however, the crystal structure of the latter rock type may reduce its potential to produce high quality aggregate.

Finding commercial scale resources in area 8 may present a challenge. According to the geological mapping, sizable mafic intrusions exist south of Steel Mountain which extend to the shore of Santoy Bay. However, this area is rugged, heavily wooded and there is no road access. It could not be fully inspected during the field assessment.

There are no existing shipping facilities in the immediate vicinity of area 8 other than the pulp dock on Peninsula Harbour (area 7). It is possible that new shipping facilities might be developed on Jackfish Bay or just south of Santoy Bay where cliffs containing mafic intrusive rocks rise approximately 120 m above lake level.

No sites suitable for sampling were identified in area 8.

3.2.9 Candidate Resource Area 9

Candidate Resource Area 9 extends from the south end of Jackfish Lake to Collingwood Bay on Lake Superior (Figure 3-10). It includes parts of the Terrace Bay Batholith and the Mount Gwynne Pluton (Carter 1988) which are both Archean age igneous intrusions of granitic composition that are part of the Wawa Subprovince.

The topographic relief in the vicinity of Terrace Bay is relatively low and bedrock outcrops are relatively few. One of the prominent geological features of this area is a succession of sand and gravel beach terraces that were deposited at the edge of the Superior basin and that blanket the bedrock for large intervals along Highway 17.

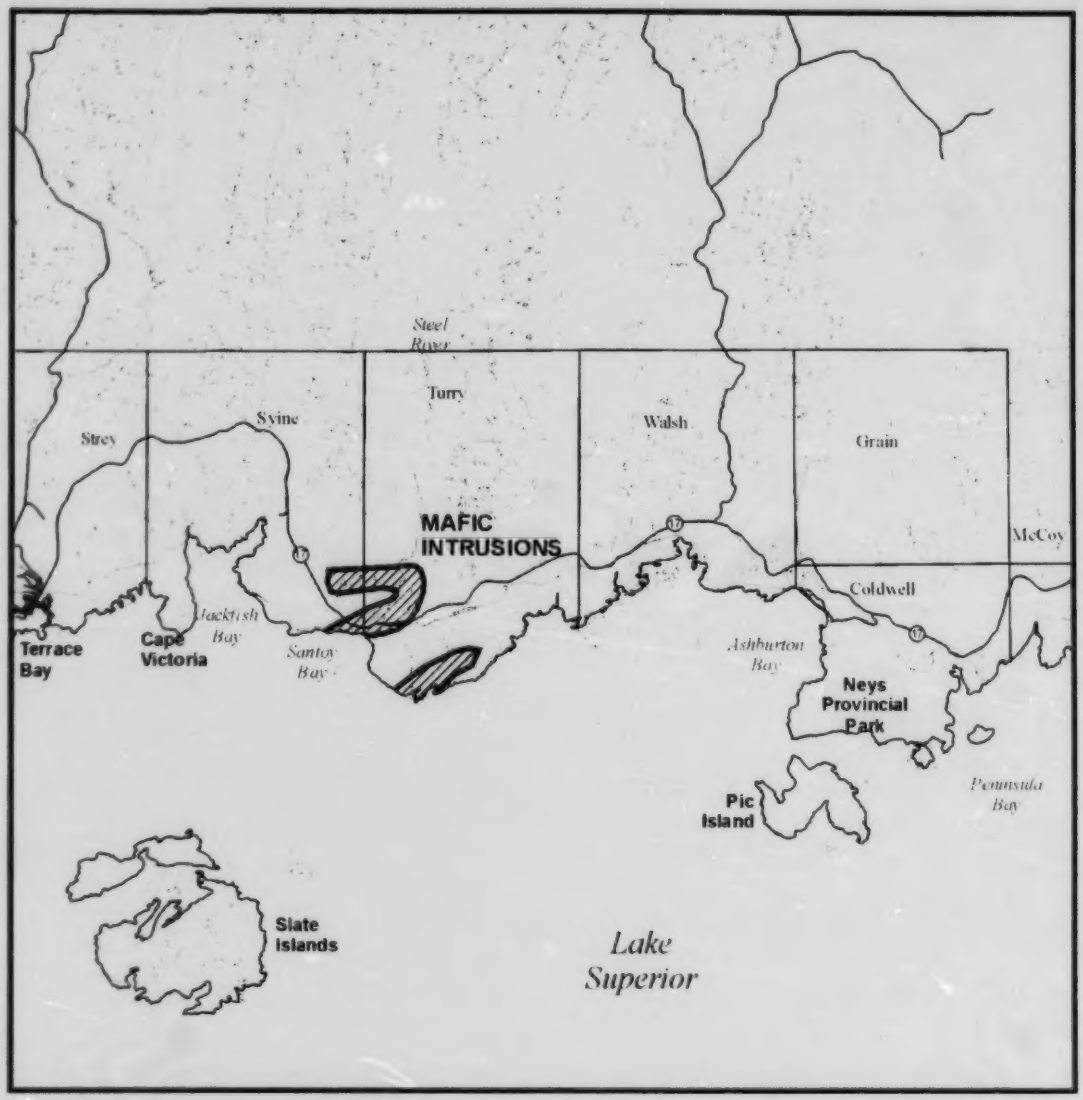


Figure 3-9: Candidate Resource Area 8

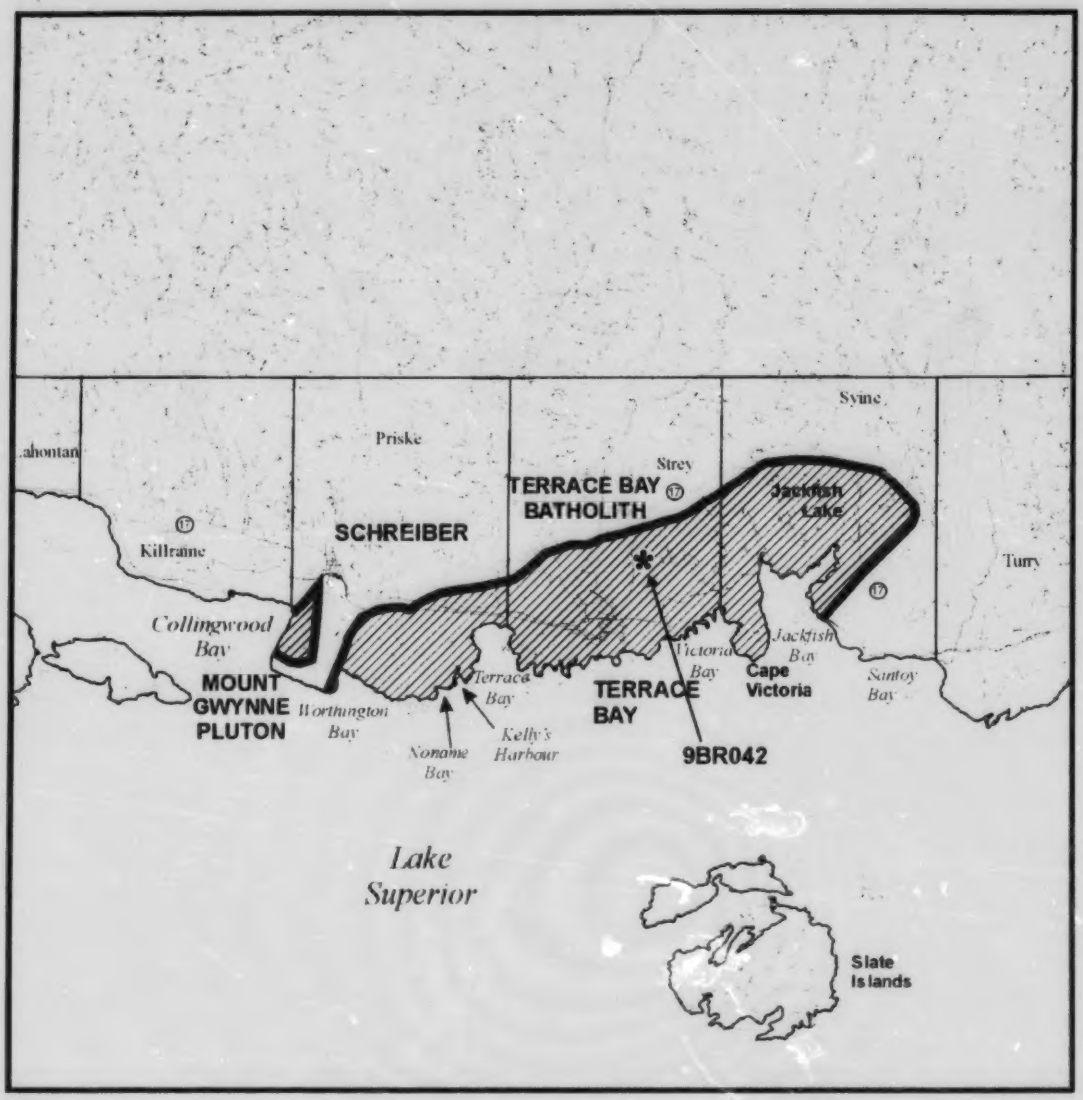


Figure 3-10: Candidate Resource Area 9

The Terrace Bay batholith is exposed adjacent to Highway 17 north of Jackfish Lake, near the Terrace Bay airport and along the shoreline of Victoria Bay. It also outcrops in the Kelly's Harbour area west of Terrace Bay where it is cross-cut by several narrow diabase dikes. The batholith is mainly composed of massive, uniform granite to granodiorite containing medium-to coarse-grained feldspar and quartz with subordinate amounts of hornblende and biotite. The rock is hard and durable, is capable of producing high quality aggregates and very large resource volumes are potentially available.

The Mount Gwynne Pluton is a fault-bounded intrusion that is exposed along the east shore of Collingwood Bay and on the Schreiber Peninsula. The Pluton is composed of massive, medium-grained, hornblende and biotite-bearing granite. In the Worthington Bay area the granite intrudes metavolcanic rocks of the Schreiber - Hemlo Greenstone Belt. The metavolcanic rocks are deformed and altered. They are considered to have low potential for high quality aggregate use.

No major marine shipping facilities currently exist in the Terrace Bay – Schreiber area. However, there are several parcels of Crown land in Terrace Bay that contain bedrock resources near the shore where new aggregate shipping facilities might be developed. Possibilities include Cape Victoria and Victoria Bay, Kelly's Harbour and Noname Bay, and selected areas between Worthington Bay and Collingwood Bay.

Several parcels of land around Terrace Bay are privately or corporately owned, or have municipal planning restrictions which will affect potential aggregate resource development in the area. Facilities near the shore include a pumping station, a hydro generating station, effluent treatment areas, a golf course, a public beach, a hiking trail, a scenic gorge (Aguasabon) and residential development. It is unlikely that any negative impacts associated with quarrying on these land uses would be permitted.

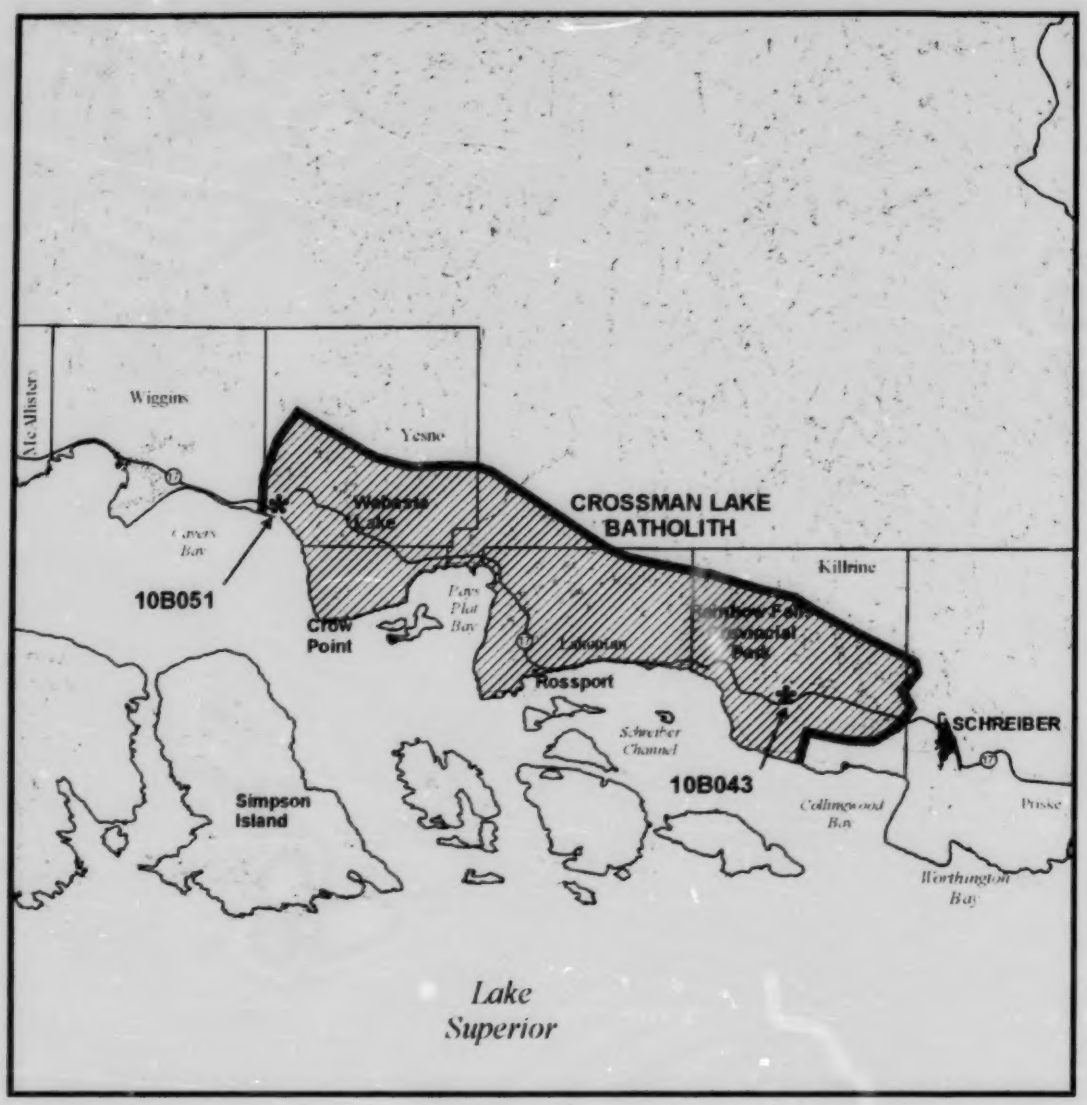
Sample 9BR042 was collected from a Highway 17 outcrop across from the Terrace Bay airport to evaluate the aggregate potential of the Terrace Bay Batholith. The test results are summarized in Table 3-1 and indicate that the sample rock potentially satisfies Ontario specifications for HL1 asphalt and concrete stone, and American equivalents. The aggregate potential of rocks in the Terrace Bay Batholith and the Mount Gwynne Pluton appears to be fairly constant based on available field data.

3.2.10 Candidate Resource Area 10

Candidate Resource Area 10 is a relatively large area that lies between Walker Lake west of Schreiber and Mountain Bay on Lake Superior (Figure 3-11). It is part of the Crossman Lake Batholith (Carter 1988) of the Wawa Subprovince. The batholith is an Archean age igneous intrusion that separates the Schreiber-Hemlo greenstone belt from the Nipigon embayment.

The Crossman Lake Batholith is a medium-to coarse-grained granite intrusion, dominantly composed of alkali feldspar and quartz with subordinate amounts of hornblende and biotite. The texture of the granite is variable and ranges from massive to porphyritic. The porphyritic granites outcrop along Highway 17 near Rainbow Falls Provincial Park and in the Rossport area, and contain coarse crystals of pink feldspar, up to 25 mm across, set in a fine-grained granitic matrix.

A number of the granite outcrops contain shear zones and localized zones with soft iron oxide coatings. Strongly foliated to schistose material was also identified in several Highway 17



LEGEND

- Massive to porphyritic granite
- ★10B043 Sample location and designation
- Boundary of Candidate Resource Area 10

N

2.5 0 10.0 km

Scale 1:250,000

Figure 3-11: Candidate Resource Area 10

rock cuts north of Rossport and in the Pays Plat – Wabasta Lake area. In addition, coarse-grained and porphyritic granites also have questionable potential to produce a uniform aggregate product. Therefore, a selective approach must be taken when considering the bedrock aggregate resources in Candidate Area 10.

Cavers Hill is a large granite knob north of Cavers Bay that has an elevation of approximately 225 m above lake level. This granite appears to be a uniform and massive, medium-grained rock capable of producing quality aggregates. It is exposed in the existing rock cuts along

Highway 17 and along an abandoned section of highway south of the present alignment. Large resource volumes are potentially available. Steep cliffs more than 150 m above the lake exist in the north part of Cavers Bay. To the south, at Crow Point, the shoreline slopes are more gradual but there is no road access to this area.

The surface topography between Rainbow Falls Provincial Park and Rossport is characterized by low relief and gradual bedrock slopes to the shoreline. The low topography may limit potential extraction depths at near-shore sites and implies shallow off-shore water depths for marine transport. In the Gravel River area, near the west limit of area 10, bedrock accessibility is reduced by a thick blanket of sand overburden.

There are no existing marine shipping facilities in the immediate vicinity of area 10; however, Nipigon Bay is navigable by lake freighter. A small commercial marina, mainly servicing pleasure craft, exists at Rossport. New shipping facilities might be considered in deep water areas with relatively high relief at the shoreline, such as in the Cavers Bay area.

Off-shore islands in the Schreiber Channel containing outcrops of diabase, gabbro and related mafic intrusive rocks were not examined in the field but appear to have limited potential as aggregate resources. The maximum relief on the islands is about 50 m above the lake. Since the mafic intrusive rocks occur as sills overlying sedimentary rock, the thickness and volume available on the islands may be limited. The islands may be accessible by barge but most of them are probably too small to support a commercial extractive operation.

To assess the quality potential of the granite in area 10, samples 10B043 and 10B051 were collected from Highway 17 rock cuts southeast of Whitesand Lake and at the west end of Cavers Hill, respectively. The aggregate test results area summarized in Table 3-1. Both test results indicate that the granite has potential to satisfy Ontario specifications for HL1 asphalt and concrete stone, and American equivalents. Based on field information, however, the aggregate potential across the Crossman Lake Batholith is variable. The greatest potential appears to be southwest of Whitesand Lake and in the Cavers Hill area to the west. Rocks in the middle part of the batholith in the Rossport-Rainbow Falls area have porphyritic textural features which suggest possible aggregate quality concerns.

3.2.11 Candidate Resource Area 11

The Nipigon diabase sills within 5 km of the Lake Superior shoreline, between MacInnes Point on Nipigon Bay and the Town of Red Rock, were collectively designated as Candidate Resource Area 11 (Figure 3-12). The sills are part of the Nipigon Embayment of the Southern Province and formed in response to the Keweenawan midcontinent rift (Sutcliffe 1991).

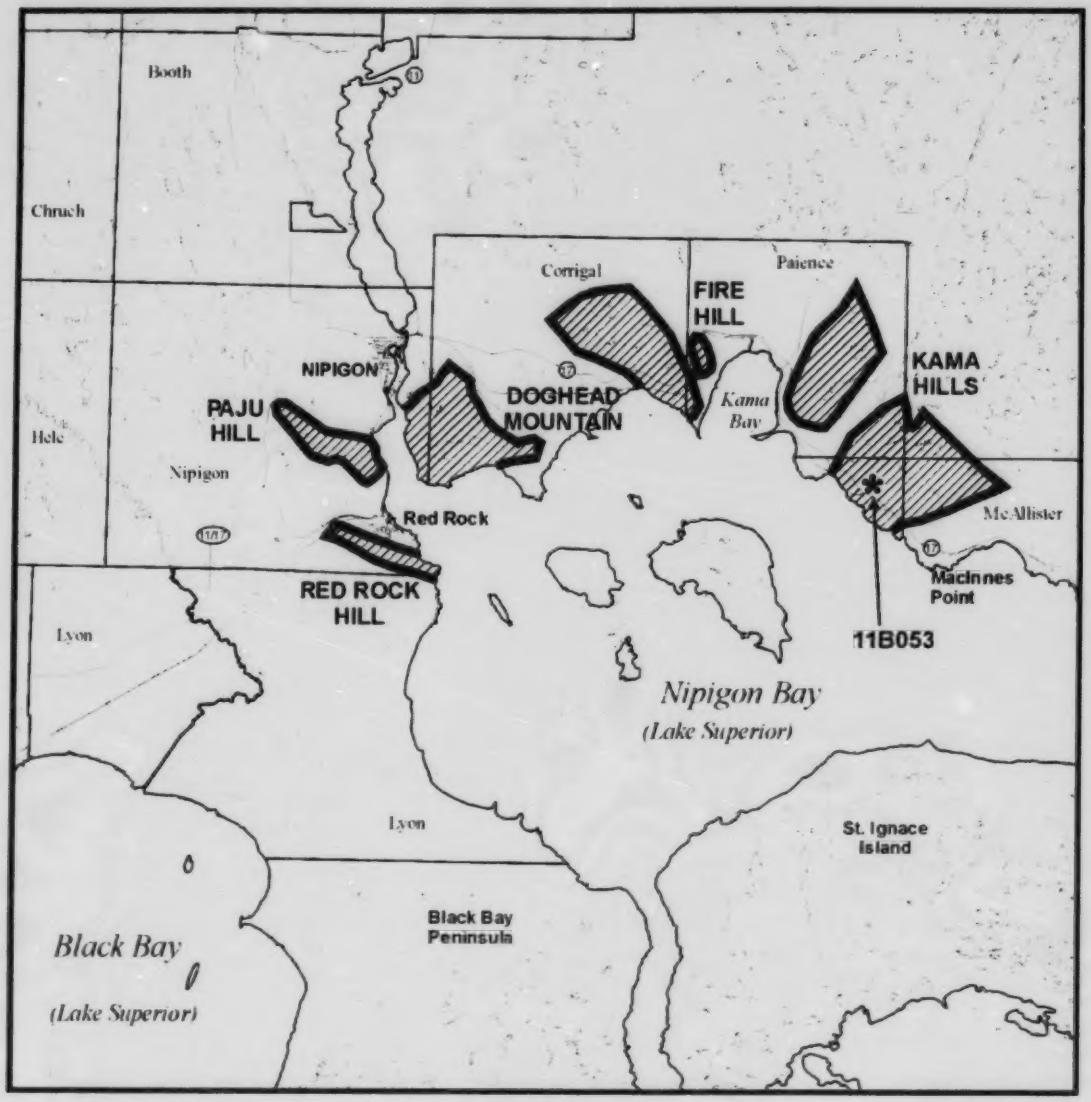


Figure 3-12: Candidate Resource Area 11

The Nipigon diabase is a fine-to medium-grained, durable rock that is mainly composed of dark coloured plagioclase feldspar and clinopyroxene. It occurs as resistant sheet-like sills that cap the large mesa landforms around Nipigon. Some of the thicker sills in the area may exhibit vertical variations in grain-size and texture, ranging from aphanitic at the margins to pegmatitic internally.

From east to west in area 11, diabase sills of significant size occur at Kama Hills, Fire Hill, Doghead Mountain, Paju Hill and Red Rock Hill (sills on off-shore islands are assigned to Candidate Resource Area 12). On average, the hills crest near elevation 165 m above lake level.

The diabase usually forms the upper 20 to 40m of the hill and the lower part of the hill is composed of Sibley Group sedimentary rocks. Significant volumes of talus have accumulated at the bases of several of the steep escarpments present in the region.

Diabase has been extracted for use as aggregate from several locations in Area 11. Diabase from a quarry in Paju Hill was used to construct parts of the Red Rock marina facility. Diabase talus blocks also have been recently removed from at least 2 permitted sites in the Fire Hill area east of Nipigon.

There are no existing shipping facilities in area 11. Both Nipigon and Red Rock have small commercial marinas, but these facilities are not equipped to handle bulk shipping vessels. There is an abandoned shipping dock adjacent to the Red Rock marina that was formerly used to service the nearby pulp mill. However, mill products are now transported by truck and rail and the old dock has fallen into disrepair. There is a possibility that the dock could be rehabilitated. New shipping facilities might be developed at alternate sites in Nipigon Bay provided water depths are sufficient.

Sample 11B053 was collected from a large Highway 17 rock cut in Kama Hills diabase just east of Kama Bay. The aggregate test results are summarized in Table 3-1 and indicate that the Nipigon diabase has high potential to satisfy Ontario specifications for HL1 asphalt and concrete stone, and American equivalents. As noted above, diabase sills cap the hills in the Nipigon area and have limited vertical thickness. Some of the hills have steep sides with the diabase occurring at a high elevation. The location of potential quarry sites will be limited to areas where diabase can be safely extracted.

3.2.12 Candidate Resource Area 12

Keweenawan igneous intrusions found on the Black Bay Peninsula and on several of the off-shore islands around Nipigon Bay were collectively designated as Candidate Resource Area 12 (Figure 3-13, back pocket). The intrusions considered in the study include the following: the Moss Lake Intrusion; diabase dikes on the Black Bay Peninsula; the diabase intrusion at the south end of Flour Island; the McEachan Lake Dike on St. Ignace Island; and the St. Ignace Island Ring Complex. Also considered were diabase sills on the north shore of St. Ignace Island and on Vert, La Grange and Burnt islands in Nipigon Bay. Large resource volumes are potentially available.

The Moss Lake Intrusion is circular, funnel-shaped body of gabbroic rocks that surrounds a central zone of basalt, quartz-feldspar prorphry and diabase east of Moss Lake (McIlwaine and Wallace 1976). The gabbros are exposed along the shore of Black Bay Peninsula at Moss Harbour and to the north adjacent to Sarat Island and also on Moss Island. The gabbros are a suite of medium-to coarse-grained, massive to porphyritic rocks composed of plagioclase and pyroxene with subordinate amounts of olivine, quartz and iron-titanium oxides. On Moss Island the gabbro is

frequently jointed and is moderately to strongly weathered with local soft zones. Sample 12B071 was collected from a competent exposure near the east shore of Moss Island to assess aggregate potential. The test results are summarized in Table 3-1. The sample had excessive absorption (1.23%) compared to HL1 asphalt stone specifications (1.0%). This result might be attributed to weathering, as the sample collected was in a remote area and all outcrops exhibit some degree of weathering.

Two large vertical diabase dikes on Black Bay Peninsula, one west of Shesheeb Bay and the other known as The Paps, are potential aggregate resources of high quality but are difficult to access. The dikes form prominent northwest trending ridges approximately 300 m wide that cross the peninsula. The diabase is very coarse-grained, except for the margins, and this may affect the aggregate quality potential. No samples from the dikes were taken.

The southwest part of Flour Island is occupied by a large diabase intrusion. Based on field evidence the intrusion appears to be a thick sill overlying mafic metavolcanic rocks. The diabase is a uniform, massive, fine-to medium-grained rock with potential to produce quality aggregate. The intrusion forms a steep rock face that rises approximately 150 m above the lake. Diabase talus has accumulated in several areas along the shore. A sample of the talus was taken and designated as 12B072. Aggregate test results are summarized in Table 3-1 and indicate excessive absorption (1.24%) compared to HL1 asphalt stone specifications (1.0%). This result is attributed to weathering.

The McEachan Lake dike on St. Ignace Island is a lenticular diabase intrusion that forms the western shore of McEachan Lake (Giguere 1975). The dike is approximately 10 km long and has a maximum width of approximately 600 m. It rises to approximately 210 m above Lake Superior. Like other diabase intrusions in the Nipigon area, the dike rock has potential to produce quality aggregates. Notably, the McEachan Lake dike is reported to have very coarse-grained zones which and these zones may reduce aggregate quality potential. No test samples from the dike were taken.

The St. Ignace Island Ring Complex is a zoned circular stock with a core of porphyritic rhyolite and an outer rim of gabbro to anorthosite (Giguere 1975). The rhyolite is a grey to greyish-brown rock composed of feldspar and quartz crystals up to 5 mm across contained within a fine-grained to aphanitic matrix. Parts of the rock in exposures appear to be competent and sound while others are brittle and have a weak internal structure. The weaker rocks are probably unsuitable for high quality aggregates. A sample of a relatively competent rhyolite was collected from a shoreline exposure on the McNab Peninsula, near the southeast end of St. Ignace Island. The sample was designated as 12B073A and the aggregate test results are summarized in Table 3-1. The sample had an excessive accelerated mortar bar expansion value (0.257%) compared to specifications for concrete stone (0.140%); this indicates the potential for alkali-silica reactions in concrete applications.

The mafic outer rim of the St. Ignace Island Ring Complex ranges from 60 m wide on the east side to 600 m wide on the west side. Outcrops at McNab Peninsula are medium to coarse-grained anorthosite, composed of plagioclase laths up to 15 mm across and pyroxene occurring locally as clusters. From an aggregate perspective, the fresh anorthosite is considerably stronger than the porphyry, however, the coarse grain size and smooth crystal cleavage are potential quality and asphalt bonding concerns. Sample 12B073B was collected to evaluate the aggregate potential of the anorthosite and test results are summarized in Table 3-1. The sample had slightly excessive

absorption (1.01%) and slightly excessive mortar bar expansion (0.144%) compared to concrete specifications.

Diabase sills occur on the north shore of St. Ignace Island and on Vert, La Grange, and Burnt islands in Nipigon Bay. The St. Ignace Island sill is a zone of diabase to gabbro approximately 200 m wide that extends approximately 750 m along the north shore of the island. The shore is a steep rock face that rises approximately 120 m above the lake. The upper part of the face consists of sedimentary and volcanic rocks. This intrusion may be too limited in extent to be a viable quarry target.

Diabase sills which intrude Sibley Group sedimentary rocks on Vert, La Grange and Burnt islands are part of the Nipigon group of sills. There appear to be a number of sills present on these islands, the sills being interlayered with Sibley sandstones. Nipigon diabase on the islands in Nipigon Bay is geologically equivalent to that on the mainland and is considered capable of producing high quality aggregate. Since test results for mainland samples indicate the quality of the diabase, no additional samples from the islands were submitted for testing.

Shoreline relief in Area 12 varies from low beaches to sheer rock faces that may rise approximately 175 m above the lake. The coastline is rugged and is dominantly exposed rock; there are numerous sheltered inlets and coves. Talus slopes at the base of high rock faces are common in the area. The interior areas of the islands are mainly undeveloped and uninhabited except for occasional hunt camps.

Water depths in Nipigon Bay and Nipigon Strait are sufficient to allow navigation by commercial vessels and close approach to the shore is possible at several locations. Mineral extraction and quarrying has been conducted at island sites in the past with products being loaded directly onto vessels moored at the shoreline.

3.2.13 Candidate Resource Area 13

Outcrops of a Nipigon sill between Dorion and Ouimet on Highway 11/17 form Candidate Resource Area 13 (Figure 3-14). The sill is composed of diabase which intrudes Sibley Group sedimentary rocks.

Both the diabase and the sedimentary rocks occur along the Highway north of Ouimet indicating that the sill is not very thick in this area. However, the sill is probably thicker, possibly more than 20 m thick, to the north on Ouimet Canyon Road. The escarpment face rises steeply above the surrounding terrain to a height of approximately 40 to 100 m. This area may have potential for extractive development.

The shoreline area of Black Bay adjacent to area 13 is too shallow for ship or barge access and an intermediate mode of transport to a deeper port, such as truck or rail, would likely be necessary to transport rock from this area. The nearest existing port facilities are at the City of Thunder Bay.

Sample 13B061 was collected from a diabase outcrop on Highway 11/17, 200 m north of Ouimet Canyon Road. The aggregate test results are summarized in Table 3-1. Like diabase sills in the Nipigon area, the Dorian Sill has high aggregate quality potential and test results satisfy Ontario specifications for HL1 asphalt and concrete stone.

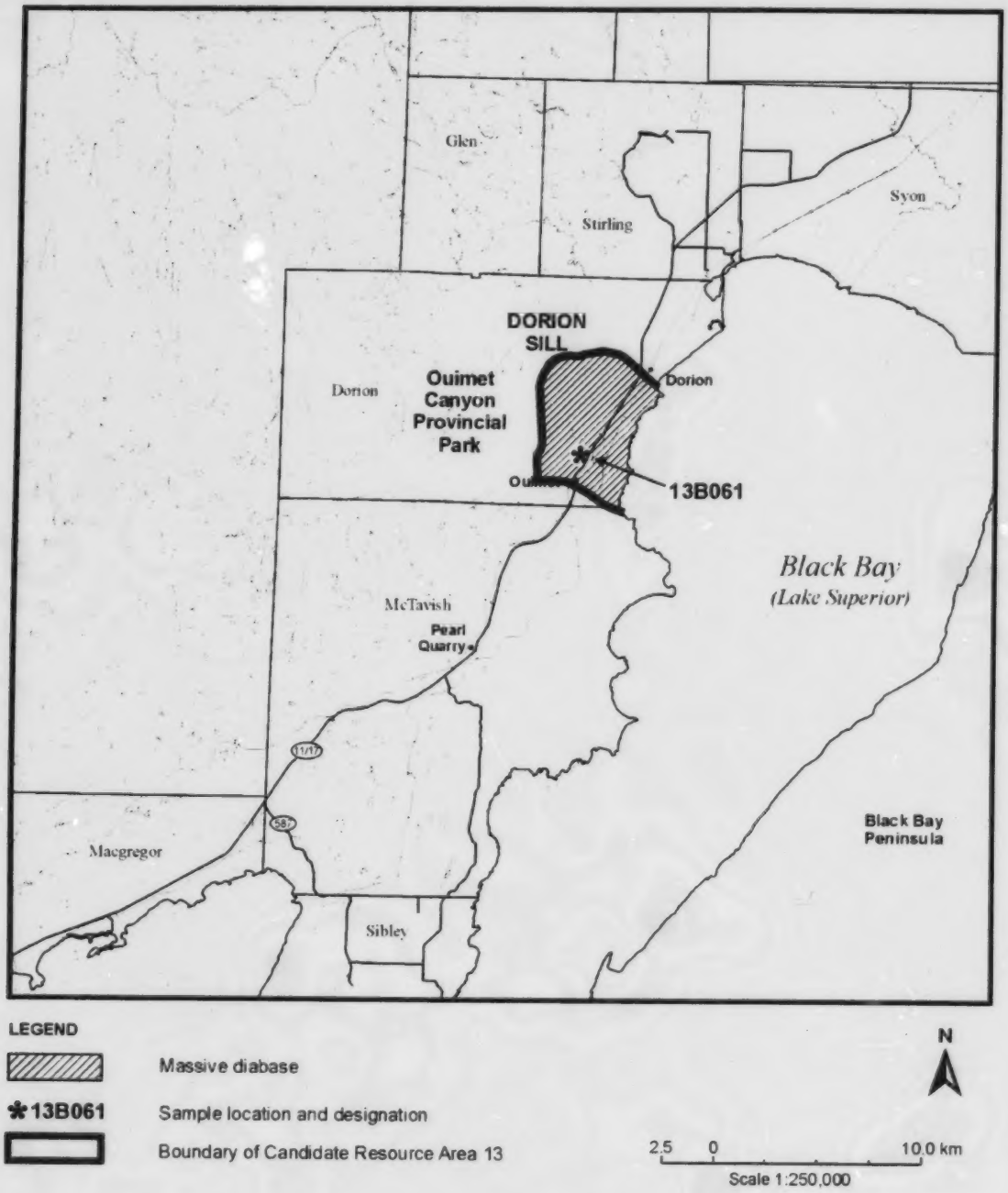


Figure 3-14: Candidate Resource Area 13

3.2.14 Candidate Resource Area 14

Candidate Resource Area 14 extends along the northwestern shore of Thunder Bay from the intersection of Highway 11/17 and Highway 587 to the City of Thunder Bay (Figure 3-15, back pocket). A variety of Archean and Proterozoic rocks occur in this area. The Archean rocks form part of the Wawa Subprovince and include a suite of metavolcanic and metasedimentary rocks and granite. The Proterozoic rocks include clastic and chemical metasedimentary rocks of the Animikie Group and Logan diabase dikes and sills. Diabases and granites contained within these rocks were assessed for their ability to produce high quality aggregate. These geological units are discussed below.

Within area 14 a large plutonic body, known as the MacKenzie Granite (Scott and Sequin 1986a, 1986b), exists northwest of Amethyst Bay. The granite is medium-to coarse-grained and has a massive to slightly porphyritic texture. It is mainly composed of feldspars and quartz with subordinate amounts of biotite. The Ministry of Transportation has a quarry in the MacKenzie Granite just off Highway 11/17 approximately 1 km west of MacKenzie Station Road. Granular and asphalt aggregates produced from the quarry have been used on local Ministry of Transportation highway construction projects.

A Logan diabase sill occurs in the west part of area 14; it is approximately centered on the Highway 527 and 11/17 intersection. The diabase is a dark grey, fine-to medium-grained, massive textured rock mainly composed of pyroxene and plagioclase. The diabase is exposed in quarries east of Copenhagen Road (Biloski quarry), south of Highway 11/17 (LTL quarry) and at the Silver Harbour quarry.

The Silver Harbour diabase quarry is no longer active and the area is now a conservation area/residential development. Notably, the quarry is located on the shoreline and the diabase was formerly extracted and shipped by barge to construct armour stone break-walls at the port of Thunder Bay. Substantial reserves of high quality diabase remain, but recent land use changes have sterilized any further extraction.

Another diabase sill, which overlies Rove shale, outcrops on Caribou Island southeast of Amethyst Harbour. The north face of this island is steep and talus exists near the base. The island relief is approximately 75 m above lake level.

The ground surface in area 14 rises to the northwest away from the lake. Shoreline relief is low and outcrops in the area are generally small, low and rounded. The MacKenzie Moraine occurs in the north part of the candidate area and relatively thick surficial deposits overlie the bedrock. Sand and gravel is extracted from several pits in the moraine.

Since much of the shoreline area of area 14 is developed with housing, opportunities to develop new aggregate shipping facilities are limited. The closest existing shipping facilities are at the port of Thunder Bay. New shipping facilities might be developed on Caribou Island to obtain the available diabase resources available at that location.

Sample 14B064 was collected to assess the MacKenzie Granite at an outcrop approximately 600 m west of MacKenzie Station Road and southeast of the Ministry of Transportation quarry mentioned above. The aggregate test results for the sample are summarized in Table 3-1 and indicate the granite has potential for use as high quality aggregate. The intrusion is large and

appears to be consistent, suggesting that a number of potential extraction sites may be available in the candidate area. No additional diabase samples were submitted from area 14.

3.2.15 Candidate Resource Area 15

Candidate Resource Area 15 is bounded by the Fort William Reservation to the north and the Canada-United States border to the south (Figure 3-16, back pocket). This area may be accessed using Highway 61.

The north part of area 15 is characterized by a series of high mesas which consist of flat-lying Logan diabase sills capping greywacke and shale of the Rove Formation. South of the Cloud River the topography changes to a series of steep-sided linear ridges separated by valleys filled with glaciolacustrine clay, silt and sand. The linear ridges are the topographic expression of a swarm of northeast-trending, vertical diabase and gabbro intrusions known as the Pigeon River dikes. The ridges rise to a maximum elevation of 225 m above Lake Superior.

As in other candidate areas, the diabase in area 15 is a competent rock that has potential to produce high quality aggregates. Large resource volumes are potentially available provided that the dikes or sills have sufficient thicknesses at the chosen location.

One of the ridges in the south part of Crooks Township is the Pine River-Mount Mollie Gabbro intrusion. The intrusion is younger than the Pigeon River dikes and is predominantly an olivine to anothorthositic gabbro. It may be distinguished from the diabases by a mottled appearance, grain-size and composition, and by the textures of trace sulphides which may occur as blebs, slivers, specs and small grains (Geul 1973). The Pine River-Mount Mollie Gabbro has the potential to produce quality aggregates, but it shows indications of being more variable than other mafic intrusions in the area.

Land use in the candidate area is a mix of residential and agricultural. Undeveloped areas are wooded. An estate-lot subdivision is presently under development on a large parcel of private land south of Sturgeon Bay. Private residential development also exists on parts of Sturgeon Bay, Cloud Bay, Little Trout Bay and Pine Bay. A conservation area and public boat launch exists on the north shore of Little Trout Bay.

Existing bedrock extractive sites in area 15 include the Fumerton quarry on Highway 61 south of Cloud River, the Memory Road quarry and several smaller "wayside" quarries where bedrock has been taken for local construction projects. Past extraction activity at these sites has been almost exclusively in shaley sedimentary rock. This is of particular interest at the Fumerton and Memory Road quarries where diabase or gabbro is available but little of it has been removed.

A sand and gravel deposit, and possibly some bedrock talus material, was formerly crushed and removed from a site located approximately 10.5 km east of Highway 61 on Sturgeon Bay Road. It is understood that the aggregate from this source was used by the Ministry of Transportation to reconstruct part of Highway 61. The extraction site backs onto a prominent ridge that is capped with a large diabase sill. The diabase is accessible and the site has potential for further extractive activity. Notably, there is significant residential development in the vicinity and the potential to develop shipping facilities in the area may be limited.

No shipping facilities currently exist in area 15. The nearest existing port facilities are in the City of Thunder Bay. Opportunities to develop new shipping facilities, where diabase or rock of similar quality is available, may exist in Mink Bay, Jarvis Bay, Crystal Bay, McKellar Point, Victoria Island and Big Trout Bay.

A diabase sample designated as 15B069 was collected from the Sturgeon Bay Road site approximately 10.5 km east of Highway 61. The aggregate test results are summarized in Table 3-1 and are indicative of high quality aggregate potential. Resource development in area 15 must be done selectively and consider that diabase occurs in linear ridges with limited lateral extent. The sedimentary rocks which the diabase intrudes are generally not suitable for use in asphalt or concrete applications.

4.0 Transportation of Aggregate

4.1 INTRODUCTION

This section of the report discusses transporting bedrock aggregates from the north shore of Lake Superior to markets in the surrounding region. Since most of the potential markets for Lake Superior aggregate are located beyond economical trucking range, the discussion is mainly focused on marine transport. Several factors of marine transport are considered, including types of vessels, port facilities and costs. Since transportation by rail is a potential alternative to marine transport, it is briefly considered.

4.2 MARINE TRANSPORTATION VESSELS

There are two types of vessels that may be used for transporting aggregates on the Great Lakes: a) a ship; and b) a tug/barge combination. These vessels are differentiated by the following characteristics:

Ship:
- self-propelled by on-board engine
- 27 person crews (approximately)
- 7.9 m water depth requirement
- 12 to 14 knot speed (loaded)
- 3000 tonnes/hour unloading capability (approximately)
- 76.2 m boom length
- 25 000 to 28 000 tonnes cargo capacity
- $55-60 million capital costs (approximately)
- $5 million docking facility (approximately)

Tug/Barge:
- barge must be towed or pushed by tug
- 8-10 person crews
- 5.2 m water depth requirement
- 7 to 8 knot speed (loaded)
- 750 tonnes/hour unloading capability (approximately)
- variable boom lengths

- 5000 to 9000 tonnes cargo capacity
- $10-12 million capital cost (approximately)
- <$1 million docking facility (approximately)

Because transportation costs significantly affect the price of aggregate, the amount of material that can be carried per shipment is an important economic consideration. Ships have a large payload capacity advantage over tug/barges. In addition, the speed of transport and efficiency of unloading for ships are significantly greater than for tug/barges. Disadvantages of ships are higher capital and operating costs, higher costs of docking facilities and the need for deeper water for carrying full loads.

There are practical limits to the size of ships that can navigate the Great Lakes. The size of the vessel is limited by the capacity of locks that allow ships to pass from Lake Superior into the Lake Huron, and from Lake Erie into Lake Ontario. The largest ships that can pass both sets of locks are called "lakers". A laker is approximately 226 m long, 24 m wide and has a minimum draft requirement of 7.9 m. Lakers operating on the Great Lakes are presently owned by 3 companies – Canada Steamship Lines, Seaway Marine Transport and Lower Lakes Towing Limited. Combined, there are over 40 self-unloading lakers in these fleets which operate under the Canadian flag and have Canadian crews.

The largest ships on the Great Lakes can go through the lock at Sault Ste. Marie, but cannot pass the other "Seaway" locks. These ships are 305 m long, 32 m wide and have a draft of up to 10.4 m. They are called "1 000-footers" and are owned by American Steamship, Bethlehem Steel, Interlake Steamship, Oglebay Norton and US Steel. The 1000-footers operate under the American Flag and have American crews. American carriers are presently not permitted to trade in Canadian domestic traffic from a Canadian port.

Tug/barge operators on the Great Lakes presently include McKeil Marine Limited of Hamilton and Purvis Marine of Sault Ste. Marie. These fleets include crane ships and barges, and bulk cargo barges.

4.3 PORT FACILITIES

4.3.1 General

The shipping season on Lake Superior is generally from April to December. Local seasonal weather conditions and ice factors determine how many days an aggregate loading dock on the north shore will be able to load vessels.

The north shore of the lake is often exposed to strong prevailing winds. Docking facilities need to be protected from driving wind and waves, and the potential scouring action of moving ice. Naturally protected harbours and bays provide opportunities to reduce costs of constructing and maintaining docking facilities for aggregate shipping compared to the requirements of more exposed locations.

4.3.2 Existing North Shore Ports

The 2 primary shipping ports on the north shore of Lake Superior are at Sault Ste. Marie and the city of Thunder Bay. Both ports have several docking facilities where aggregates may be loaded onto a ship or barge. General details are as follows.

Primary Port Facilities:

Port and Dock	Draft (m)	Length (m)	Restrictions	Rail (Y/N)	Comments
Sault Ste. Marie:					
Algoma L Dock	6	549	None	Yes	None
Algoma Purvis	8	189	246 m	Yes	Gravity fed ship loader, previously handled sand and gravel outbound.
Reiss Lime	6	267	194x22 m	Yes	None.
Thunder Bay:					
Thunder Bay Terminals Ltd.	9	229	None	Yes	Shiploader, handles coal and potash.
Valley Camp	8	744	None	Yes	Two loading bridges, handles salt, stone, coal, potash.
Lafarge	7	274	None	Yes	No shiploading capability, handles limestone.
Avenor	6	183	181x18 m	Yes	None.

Between Sault Ste. Marie and Thunder Bay there are 4 secondary docking facilities which could be used for shipping aggregates. These docks are privately owned and are operated, or have in the past been operated for specific uses. Upgrades may be required to facilitate aggregate storage and handling, and permit regular shipping traffic. Available information for these docks is as follows.

Secondary Port Facilities:

Dock	Draft (m)	Length (m)	Rail (Y/N)	Comments
Michipicoten	7	386	Yes	Operated by Carlos Environmental Inc., formerly handled iron ore, limestone, coke and iron fines.
Heron Bay	7	146	No	Operated by Lafarge, receives bulk ce-ment powder, pneumatic unloading pipes.
Marathon	6	140	Yes	Operated by Marathon Pulp Inc., receives fuel, soda, salt, coal and limestone, ships pulp.
Red Rock	unknown	unknown	Yes	Dock no longer operated, owned by Norampac (Domtar), formerly shipped pulp

4.3.3 New Facilities

Rather than using the existing port facilities described above, it is possible that new shipping facilities could be constructed for transporting aggregate from the north shore of Lake Superior. Construction of a new facility has the following advantages: it could be independently owned and operated by the aggregate producer; interference with other shipping could be eliminated; it could be designed specifically for handling aggregate and aggregate shipping vessels; and there is the potential to locate dock close to the resource to minimize handling costs.

The construction of new docking facilities on the north shore should consider areas where sufficient water depth exists near the shore, locations that are protected from wind and waves, and locations that are not restricted by existing development. Natural harbours, bays, inlets and the leeward sides of islands located close to high quality bedrock resources are the most likely candidate sites for developing new shipping facilities.

A summary indicating the potential for developing new shipping facilities in each of the 15 Candidate Resource Areas is provided below. Development potential is classified as high, moderate or low based on a preliminary review of available water depths, shoreline exposure to wind and waves, and other site specific factors.

Water depth statistics were obtained from 1:600 000 hydrographic mapping Chart #LC2300 of Lake Superior published by the Canadian Hydrographic Service (1998). "Deep water" indicates that water is navigable by fully loaded ships (generally greater than 10 m).

Shoreline exposure to wind and wave impacts is rated using the following broad-based descriptive terminology: protected; moderately exposed; and highly exposed. Descriptions based on visual assessments of shoreline areas and topographic information.

Protected shorelines include natural harbours, inlets, and bays, and the leeward side of islands and channels, which normally have calm water conditions for most of the shipping season and are protected from strong winds by natural topographic features. Moderately exposed shorelines include areas that have limited natural protection from wind and waves, and include large bays and some areas with off-shore barrier islands. Enhanced docking structures will normally be required to develop shipping facilities in moderately exposed areas. Highly exposed shorelines are unprotected shorelines which receive the unabated impact of wind and waves directly off the lake. Development of shipping facilities in these areas will require elaborate breakwall and harbour construction. Highly exposed areas are considered to have low development potential for shipping facilities.

<u>Shipping Facility Development Potential</u>

Area 1 - Goulais Bay: deep water approaches north of Gros Cap but shallow shoals in St. Mary's River inlet; moderately to highly exposed; variable shoreline relief; existing residential properties in area; moderate development potential

Area 2 - Batchawana Bay: deep water bay but shallow shoals north and south of Batchawana Island; protected shoreline; generally low shoreline relief; existing residential properties in area ; low development potential

Area 3 - Montreal River: deep water approaches; moderately to highly exposed shoeline; generally steep, rugged shoreline; some private property in area; moderate development potential

Area 4 - Minnekona Point (Michipicoten): deep water approaches; highly exposed shoreline; undeveloped area; near Michipicoten dock facility; low development potential

Area 5 - Floatingheart Bay: deep water approaches; highly exposed shoreline; undeveloped area; low development potential

Area 6 - Playter Harbour: variable water depth; protected to moderately exposed irregular shoreline; near Heron Bay dock; parkland and First Nation lands near shore; low development potential

Area 7 - Marathon: generally deep water approaches with some shallow areas and off-shore islands; protected bays and harbours; irregular and rugged shoreline; variably developed with large areas of private land; existing Marathon Pulp Inc. dock; high development potential

Area 8 - Steel River: deep water approaches with some shallow shoals; moderately to highly exposed shoreline; variable shoreline relief; limited private property to undeveloped; low to moderate development potential

Area 9 - Terrace Bay: variable water depths with some hazardous navigation areas; moderately exposed shoreline; irregular shoreline with low to moderate relief; restrictive shoreline development and municipal planning factors; low to moderate development potential

Area 10 - Pays Plat Bay: generally deep water approaches; protected shoreline; variable relief with some steep, rugged cliffs; variable shoreline development; moderate to high development potential

Area 11 - Nipigon: generally shallow water near shore with narrow navigation channels; protected shoreline; abandoned shipping dock at Red Rock; variable shoreline development; industrial areas; moderate development potential

Area 12 - Black Bay-St. Ignace: deep water but potentially hazardous navigation near shore; protected to highly exposed shoreline; remote/island locations; undeveloped; rugged shoreline with variable relief; previous shipping of mineral resources and dimension stone; moderate development potential

Area 13 - Dorion: shallow water (<5 m) in north part of Black Bay; protected shoreline; low shoreline relief; some private properties in area; low development potential

Area 14 - Shuniah: variable water depths with some shallow approaches; protected to moderately exposed shoreline; significant private development in area; close to Port of Thunder Bay; low development potential

Area 15 - Neebing: variable water depths with potentially hazardous navigation; moderately exposed to protected shoreline; irregular shoreline with numerous bays and inlets;

generally rugged area; variably developed with private property; low to moderate development potential

Costs to construct new docking facilities will vary substantially, depending on location and requirements. Receiving dock designs can range from large, elaborate structures based on engineered fill to simpler systems consisting of a group of off-shore mooring piles ("dolphins"). Self-unloading vessels (see Section 4.4.2) will have cost advantages because of their ability to rapidly discharge commodity cargoes without needing shore-based unloading equipment. Barges can also be rigged for self-unloading and require relatively simple loading systems. Lower cost facilities can be constructed with these capabilities in mind.

The appropriate cost to construct a ship loading dock with supporting marine structures (i.e., 4 or 5 "dolphins" along which the ship would rest and tie up against and approximately 30 m of conveyor for handling aggregate) is estimated to be in the order of $5 million at the present time.

4.3.4 Receiving Ports

Many of the major urban markets being considered in this study have a Great Lakes receiving port or are within trucking distance from one. The capabilities of the receiving ports are important when considering marine transport of aggregates from the north shore of Lake Superior.

The receiving port needs to have sufficient water depth to permit safe entry and dockage of loaded aggregate vessels. Great Lakes aggregate receiving ports are tabulated in Table 4-1. Fully loaded aggregate ships have a minimum 7.9 m draft requirement.

The receiving port must also have material storage and handling area to manage potentially large shipments of aggregate. Wharfage and pile management charges, ranging from about $2 to 4 per tonne may apply at some destinations, will affect the final cost of the aggregate. In most instances, the receiving port will have to act as a source depot for secondary transport (e.g., trucking or rail) of aggregate to the final point of use.

4.4 COSTS OF MARINE TRANSPORT

4.4.1 General

The cost of transporting aggregate by water from the north shore of Lake Superior to its ultimate point of use has 3 basic components:

- the cost of loading and unloading the vessel;
- the cost of navigating the vessel from the loading port to the receiving port;
- the costs of storage and haulage of the point of use.

TABLE 4-1: GREAT LAKES AGGREGATE RECEIVING PORTS

LAKE	PORTS WITH DRAFT >7.9 m		PORTS WITH DRAFT <7.9 m	
	PORT	DRAFT	PORT	DRAFT
Lake Superior	Duluth, MI	6.7-8.2	Marquette, MI	7.0
	Superior, WI	7.6-8.2	Washburn, WI	6.7
	Thunder Bay, ON	6.7-9.1		
Lake Huron	Fisher Harbr, ON	9.1	Courtright, On	6.1
	Goderich, ON	8.2	Depot Harbour, ON	6.4
	Mackinac Is., MI	11.0	Drummond Is., MI	7.0
	Sarnia, ON	7.0-9.1	Heron Bay, On	6.7
	Sault Ste. Marie, ON	4.6-8.2	Marine City, MI	6.7
	Spragge, ON	8.5	Marysville, MI	7.0
	Whitefish Bay, ON	9.1	Stoneport, MI	7.9
			Midland, ON	7.6
			Mooretown, ON	4.9
			Owen Sound, ON	6.7
			Parry Sound, ON	6.4
			Port Huron, MI	6.7
			Saginaw, MI	6.1-6.7
			Sault Ste. Marie, MI	7.9
			St. Ignace, MI	6.7
			Sombra, ON	5.5-7.0
Lake Michigan	Chicago/Calumet, IL	6.1-8.2	Bay City, MI	6.7-7.6
	Charlevoix, MI	8.2	Benton Harbor, MI	5.5
	Hanock, MI	7.9	Ferrysburg, MI	6.4
	Indiana Hbr, IN	6.7-8.5	Grand Haven, MI	6.4
	Ludington, MI	5.5-9.1	Green Bay, WI	5.8-7.6
	Milwaukee, WI	5.8-8.2	Ironton, MI	5.8
	Muskegon, MI	7.00-9.13	Holland, MI	6.1-6.7
	Port Inland, MI	8.5	Manitowoc, MI	6.4
	Burns Harbor, IN	8.2	St. Joseph, MI	5.2-5.8
	Gary, IN	8.5	Waukegan, IL	4.9-6.7
Lake Erie	Ashtabula, OH	4.9-8.5	Amberstburg, ON	6.4
	Conneaut, OH	8.5	Buffalo, NY	6.4-7.9
	Cleveland, OH	6.4-8.2	Essexville, MI	6.1-7.6
	Detroit, MI	6.4-8.5	Fairport, OH	6.1-7.3
	Erie, OH	7.6-8.5	Harsens Is, MI	6.7
	Huron, OH	8.5	Kingsville, ON	4.9
	Lorain, OH	7.9-8.2	Port Clinton, OH	3.0
	Thorold, ON	8.2	Port Stanley, ON	6.4
	Toledo, OH	5.5-8.2	Sanduskey, OH	4.3-6.7
	Windsor	6.4-9.4		
Lake Ontario	Hamilton, ON	8.2	Oshawa, ON	7.9
	Mississauga, ON	9.1	Oswego, NY	6.4-7.3
	Ogdensburg, NY	5.5-8.2	Picton, ON	6.7
	Port Weller, ON	8.2	Rochester, NY	5.5
	Prescott, ON	8.2		
	Toronto, ON	6.1-8.2		
	Welland, ON	8.2		

Note: Draft depths subject to lake level fluctuations.

4.4.2 Loading/Unloading

Loading of aggregate vessels is a demanding process that is usually done with a conveyor belt system. Costs may be affected by draft restrictions at the loading or receiving port and costs will generally increase if water depths at the dock are too shallow to load the vessel to full capacity. Ships are sometimes partially loaded and then "topped off" to maximum draft in deeper water. Aggregate producers normally include loading in the base price of their aggregate and sell it f.o.b. (freight on board) the transport vessel.

Presently, almost all of the aggregate transported on the Great Lakes is carried in self-unloading ships or "self-unloaders."

Self-unloaders have one or more on-board conveyor systems running the full length of the cargo area. Aggregate falls through a series of gates in the bottom of the cargoholds onto the conveyor, and is then moved to the bow or stern area where it is elevated to deck level. A second conveyor system, called the "boom", moves the aggregate from the ship to the dock. Boom lengths vary, but are normally about 75 m long.

Self-unloading barges are also available. On-board conveyors move the aggregate to a conveyor system normally located at the side of the barge. This conveyor takes the aggregate to an unloading boom. Boom lengths for self-unloading barges are generally much shorter and unloading rates are slower compared to ships.

Self-unloading capability for aggregate vessels allow these vessels to unload at sites that have little investment in receiving facilities. For example, self-unloading ships can unload 27 000 tonnes of aggregate in about 9 hours. In the same time period, self-unloading barges can unload about 6800 tonnes.

4.4.3 Navigation

The cost of sailing a freight vessel from the port of origin to the receiving port is a function of the time to perform the following operations:

- navigation to the mooring and loading point;
- loading;
- navigation to the receiving port;
- unloading.

The owner of the vessel normally incurs the following costs with the voyage:

- fuel, crew costs, maintenance and overhead;
- charges for passing through canals, or for using pilots;
- marine service fees for navigational aids, dredging and other services such as icebreaking;
- charges for entering ports.

Canadian self-unloaders have normal operating costs of approximately $25 000 per day. It takes a ship approximately 1 day to navigate from Sault Ste. Marie to Thunder Bay. This time should be approximately doubled for a tug/barge.

4.4.4 Storage/Haulage

Receiving ports may charge fees for unloading and temporarily storing the aggregate. The costs will vary depending on the tariff of the port authority.

Additional costs will be incurred to load the aggregate onto trucks for haulage to the point of use. Costs for trucking will vary significantly with the total volume of the order, truck sizes and the distance hauled.

4.5 FREIGHT RATE COMPARISONS

Based on the above discussion, the main difference in marine transportation costs charged by vessel owners are related to shipping distances and the type of vessel used. Using current shipping rates as an approximate guide, ship owners will charge approximately $1.50/tonne more to transport aggregate from western Lake Superior (Candidate Areas 7-15) to lower lakes markets compared to transporting aggregate from eastern Lake Superior (Candidate Areas 1-6). Alternatively, a tug/barge owner will charge between $5.25/tonne and $9.75/tonne more than a ship owner to transport aggregate from eastern Lake Superior to the lower lakes and an additional $3.25/tonne to transport aggregate from western Lake Superior.

Because of their larger cargo-carrying capabilities, greater speed and faster self-unloading capabilities, ships generally have freight rate advantages over tug/barge combinations. As previously mentioned, however, ships have higher capital and operating costs and require deeper, more elaborate ports than tug/barges. This extra cost may be disadvantageous depending on the location of the aggregate resource. Additional cost comparisons for transporting aggregate by self-unloading ship and tug/barge to 4 major ports near urban markets are provided in Table 4-2.

TABLE 4-2: TRANSPORTATION COST COMPARISONS

A. Estimated Transportation Cost from West End of Lake Superior (Candidate Areas 7-15) to lower lakes destinations[1]

$ CDN per tonne	Tug/Barge	Ship	Cost Difference
Payload:	**8000 tonnes**	**25 000 tonnes**	
Destination:			
Chicago, IL	$16.50	$9.50	$7.00
Cleveland, OH	$16.50	$8.75	$7.75
Detroit, MI	$14.30	$8.30	$6.00
Toronto, ON	$22.00	$10.50	$11.50

B. Estimated Transportation Cost from East End of Lake Superior (Candidate Area 1-6) to lower lakes destinations [1]

$ CDN per tonne	Tug/Barge	Ship	Cost Difference
Payload:	**8000 tonnes**	**25 000 tonnes**	
Destination:			
Chicago, IL	$13.35	$8.00	$5.25
Cleveland, OH	$14.35	$7.25	$7.10
Detroit, MI	$12.15	$6.80	$5.35
Toronto, ON	$18.75	$9.00	$9.75

C. Transportation Costs from Eastern Lake Superior to lower lakes destinations – Self-unloading Ship [1]

$ CDN/tonne	Chicago	Cleveland	Detroit	Toronto
25 000 tonnes	$8.00	$7.25	$6.80	$9.00
Seaway tolls	n/a	n/a	n/a	$1.15
Pile maintenance	$3.85	$3.05	$2.90	$1.00
Load to truck[2]	Included	included	included	included
Wharfage	n/a	n/a	n/a	$0.15
Storage	not included	not included	not included	not included
Total	$11.85	$10.30	$9.70	$11.30

D. Transportation Costs from Western Lake Superior to lower lakes destinations – Self-unloading Ship [1]

$ CDN/tonne	Chicago	Cleveland	Detroit	Toronto
25 000 tonnes	$9.50	$8.75	$8.30	$10.50
Seaway tolls	n/a	n/a	n/a	$1.15
Pile maintenance	$3.85	$3.05	$2.90	$1.00
Load to truck[2]	Included	included	included	$1.50
Wharfage	n/a	n/a	n/a	$0.15
Storage	n/a	n/a	n/a	n/a
Total	$13.35	$11.80	$11.20	$14.30

Notes:

(1) Prices shown above are:
   a) indicative of prices charged for these services in October 2000
   b) US dollars are converted to Canadian dollars at USD 0.65 buys CDN 1.00

(2) Includes truck weighing and weigh ticket

(3) n/a – not applicable

4.6 RAIL TRANSPORT

Rail transport of Lake Superior aggregate may be a viable alternative to marine transport where rail connections are available near the resource. It may be possible to use an existing spur line near the resource, otherwise, trucking or construction costs will be incurred moving aggregate to the railhead. Open top hopper cars can carry approximately 92 tonnes of aggregate each and can be linked in tandem with multiple shipments per week.

Table 4-3 below provides cost information for rail transport of aggregate based on current rates from CP Rail. Nipigon, Ontario is assumed to be the departure point, and no trucking, transfer or delivery charges are included.

Table 4-3: Estimated Costs of Rail Transport of Aggregate (from Nipigon, Ontario)

Destination	$CDN/tonne
Winnipeg, Manitoba	17.50
Puslinch, Ontario (Near Milton)	25.75
Chicago, Illinois	46.75

With additional handling costs included, rail transport of Lake Superior aggregates is expected to be more expensive than marine transport.

5.0 Economics

5.1 INTRODUCTION

This chapter examines the potential economic feasibility of extracting bedrock aggregates at sites near to Lake Superior and successfully developing markets for high quality crushed stone in metropolitan areas around the Great Lakes. The discussion is presented in 3 sections:

- Section 5.1 examines the suitability of each of the 15 candidate areas along the north and east shores of Lake Superior for aggregate extraction on the basis of a number of supply market economic factors. This section also explores the impact of these supply market factors on the potential facility scale and production costs;

- Section 5.2 reviews the market for high quality crushed stone in the United States, present and future trends in this market, and the potential opportunities for importing high quality crushed stone from Canada;

- Section 5.3 explores 14 metropolitan areas located in proximity of the Great Lakes, considered demand markets. Each demand market is assessed in terms of present and future supply and demand for crushed stone and high quality crushed stone. In each case an assessment is made as to the feasibility of developing markets for high quality crushed stone transported from potential sites within the Lake Superior study area.

A number of data sources have been accessed in order to support the analysis and conclusions set out below. Data, publications and other information have been gathered from the United States Geological Survey (USGS), state geological societies, national and state associations representing aggregates producers, state departments of transportation and the United States Census Bureau (United States Census Bureau 1999, 2000; United States Geological Survey 1998, 1999, 2000; United States Department of Transportation 1996). In addition to these secondary sources, informal interviews were conducted with a number of relevant persons in the United States Geological Survey, state geological societies and state departments of transportation for each of the 8 states covered in this section.

5.2 SUPPLY ANALYSIS

5.2.1 General

The Lake Superior study is considering the suitability of extracting bedrock aggregate along the north and east shores of Lake Superior. Fifteen candidate areas have been selected on the basis of geology and aggregate resource potential. The suitability of each of these sites for aggregate extraction is also assessed on the basis of a number of supply market economic factors including:

- Availability of labour;
- Suitable business and community support for aggregate extraction ventures;
- Costs of production;
- Ease of transportation links between the extraction sites and the ultimate demand markets.

5.2.2 Potential Facilities

The economic feasibility of developing a candidate area for aggregates extraction has a great deal to do with the ideal size of facility. An examination of existing facilities in Ontario and the United States is used in order to gauge an appropriate facility size to use in the present analysis.

- The average United States production is just under 400 000 tonnes of crushed stone per quarry;

- Much larger American facilities are common, however, with about 12 percent producing over 1 million tonnes per year (accounting for about half of the American production);

- Very large United States facilities, those producing over 2 million tonnes per year are not common. About 3 percent of operations fall into this category;

- The largest Ontario quarry produces over 5 million tonnes of crushed stone, and there are 7 quarries in Ontario that produce in excess of 1 million tonnes per year.

Potential facilities in the study area will likely be larger than averages in either the United States or elsewhere in Ontario. Several factors support this expectation:

- Many of the potential quarry sites would require an investment in loading/docking facilities of approximately $5 million (refer to Section 4.3.3). At a standard 10 percent cost of capital, this investment would impose costs on the facility of about $500 000 per year. Production has to be sufficiently high in order to spread out such a large site specific production cost;

- The uniformity and accessibility of the bedrock varies from one candidate area to another (refer to Section 3.2). Many of the areas, however, have very large accessible bedrock resources, with relatively minimal overburden. The physical geology of these sites would support large facilities;

- In the vast majority of cases, potential facility sites are relatively unencumbered by competing development uses for the land and opposition by local residents. This also supports the ability to operate a large facility, comparative to operations in southern Ontario.

A typical potential facility in the study area would likely be a large to very large scale operation, producing at least 1.5 million tonnes of crushed rock per year. It is of note that some quarries in Ontario are considerably larger than this estimate. The facility located on Manitoulin Island, for example currently produces about 3.8 million tonnes per year, and Canada's largest

quarry, located in Milton Ontario produces about 5.8 million tonnes per year (Aggregates and Roadbuilding Magazine, July 1999).

Assuming a selling price in the $9 to $13 f.o.b. per tonne range, such a quarry would be a $13 million to $20 million a year operation. (All monetary values in the economics section of this report are expressed in Canadian dollars based on 2000 average exchange rate of 67.3 cents to the American dollar). Based on typical employment levels (including office, quarry and plant) in the crushed stone industry, such a quarry would generate between 70 and 80 direct jobs.

5.2.3 Candidate Areas

Fifteen candidate areas were chosen for this study on the basis of their geological potential to produce high quality crushed rock. These areas are presented as broad regions in which multiple possible extraction sites could be identified. The candidate areas range across the east and north shores of Lake Superior from Goulais Bay (about 25 km north of Sault Ste. Marie) to Neebing (about 50 km south of Thunder Bay).

Most of the candidate areas are accessible by major roadways, in most cases Ontario Provincial Highway 17. Three of the identified areas are not reached by roadways, these include Minnekona Point (about 25 km west of the town of Wawa), Floatingheart Bay (about 60 km west of Wawa) and Black Bay-St. Ignace (about 65 km south of Dorion). Roadway and highway access is an important factor in assessing economic feasibility, even for facilities that load the crushed stone directly onto marine vessels, as firms rely on roadway access for supplies and labour.

5.2.4 Access to Labour Markets

A number of factors come to play in assessing the viability of the candidate areas in terms of access to labour markets.

Proximity to major communities. Areas that are judged to be within a reasonable commuting distance of a major population centre are considered more suitable candidates to support viable extraction facilities.

Table 5-1: Local Communities Within Study Area

In Excess of 80 000 Population (1996)	Between 4000 and 9999 Population
Thunder Bay	Marathon
Sault Ste. Marie	Wawa
	Terrace Bay/Schreiber

Source: 1996 Census of Canada

Five communities have been identified within the broad economic region surrounding the study area. Each of the identified communities are in excess of 4000 in population and thus of sufficient size to reasonably support a labour force with sufficient diversity from which extraction facilities would be able to draw workers. These include 2 communities in excess of 80 000 population and the remaining 4 communities with between 4000 and 10 000 persons.

Twelve of the 15 candidate areas lie within 100 km of one of the identified communities. Two of these areas, however, are without normal road access (Minnekona Point and Floatingheart Bay). Thus, only 10 areas can reasonably expect to draw labour from the labour force resident within existing communities.

Company Housing. It is not necessarily a requirement that labour for natural resource extraction facilities is drawn from existing communities. Mines can create communities by housing labour in temporary camps or developing housing and new communities closer to the extraction site. These practices are widespread in the metallic mineral extraction industry. However, these options present significantly higher costs of operations, through a requirement to offer higher wage or through company housing development costs, or both. Higher productivity and commodity prices, likely make company housing a more viable option for the metallic mineral extraction industry than for the aggregates extraction industry.

Unemployment Rates. Relative levels of unemployment in the selected communities can influence the availability (and mobility) of labour. In 1996 the unemployment rate in the 5 existing communities in the study area varied considerably between about 6.7 percent to over 15 percent (Census of Canada 1996). Unemployment rates are cyclical and subject to change from year to year, and are also sensitive to structural economic factors such as openings and closures of facilities by major employers. The 1996 Census data does highlight that unemployment rates are higher in northern Ontario than in southern Ontario. This is also considered to be a long-term phenomenon. Higher systemic unemployment in the local communities, therefore, may represent a mitigating factor against other labour supply constraints – promoting, for example, greater willingness to relocate or commute reasonably long distances.

Relative Wage Rates. Using data on an Ontario-wide basis, an analysis of relative wage rates presents some additional constraints to labour availability to new aggregate extraction facilities. The main competing industries in the local communities that would draw from a similar labour pool to the aggregate extraction facilities would be mining, manufacturing and forestry. However, an examination of typical wages by industry in Ontario reveals that the aggregates extraction industry is at a competitive disadvantage against these other industries in terms of typical wage offers.

In 1999, for example, average weekly earnings for employees of quarries and sand pit operations were 5 percent below forestry, 27 percent below other mining and 4 percent below manufacturing wages (Statistics Canada 1999). Moreover, the relative industrial composition of the communities within the study area is more heavily weighted toward these sectors than in southern Ontario. Therefore, potential aggregate extraction facilities within the study will be placed at a more acute competitive disadvantage in comparison to a similar facility in southern Ontario. As a net result, northern facilities may face situations where higher than typical wages will have to be offered and these in turn will affect the overall costs of production for the facilities and therefore the viability of the operation.

There is a mix of influences on the potential viability of aggregate extraction facilities within candidate areas with respect to access to labour. Some of the areas are sufficiently close to existing communities to draw from the constituent labour markets with relative ease and without additional costs. Many of the candidate areas, however, are farther from existing communities and attracting labour may be difficult. Wage premiums and labour constraints may make potential aggregate extraction facilities in some of those areas uneconomical.

5.2.5 Access to Community Support Services

Not only would new extraction facilities need to draw from local labour markets, but their operations as on-going businesses would have to rely on a number of community and business support systems. A potential aggregate extraction facility of the scale described previously could be a $20 million a year operation (revenue stream) and could employ directly up to 80 persons. Potential facilities within the study area have the potential to be much larger. A business of this size relies on a wide variety of support and ancillary services including firms in financial services, legal services, training and education, equipment maintenance, etc. As a general "rule of thumb" a sufficient community and business support network in existing communities of at least 10 000 persons would be required.

The distance criteria can be more flexible than in the analysis of labour markets, in the case of assessing proximity between the facility site and the supporting community. There will be less on-going interaction between the firm and its support network than between the firm and its labour resources and it is reasonable to expect that the firm will be able to obtain these services from greater distances.

The candidate areas were examined in the context of proximity within 200 km of existing communities of 10 000 population or greater. The communities in excess of 10 000 in general proximity to the study area are Sault Ste. Marie and Thunder Bay.

Nine of the 15 candidate areas are within 200 km to one of these larger urban communities. These include: Goulais Bay; Batchawana Bay; Montreal River; Plays Plat Bay; Nipigon Bay; Black Bay-St. Ignace; Dorion; Shuniah; and Neebing. This and the labour market criteria are summarized in Table 5-2.

It is possible that the relationship between facilities and their support networks will change over time as communications technology and other factors impact that relationship. Thus this aspect of the supply constraints analysis should be considered less important than the labour availability aspect.

5.2.6 Other Economic Issues

The suitability of each candidate area can also be examined within the context of other potential on-site costs that would impact the overall costs of production and therefore impact the potential viability of a facility.

Within this context, costs should be considered in relation to existing, viable aggregate extraction facilities located in less remote locations. In a relative manner, the remote areas within this study may face higher on-site production costs for items such as:

- equipment purchase and transportation to the site;
- equipment maintenance by manufacturer;
- availability of engineering consultants and other business inputs;
- roadways and other secondary transportation systems.

The remoteness of the candidate areas also leads to certain advantages over similar operations located closer to the potential demand markets. These include:

- potentially easier permitting process with less proximity to existing residential areas;
- fewer concerns over noise and site remediation;
- fewer concerns by municipalities of wear and tear of existing transportation networks.

5.2.7 Transportation

One of the key issues that impacts the ultimate viability of a candidate area from a supply economics standpoint is the ease at which the aggregate can be transported to potential demand markets. The principal advantage of the candidate areas as a whole over some of their competing facilities located closer to the demand markets is their proximity to marine transportation on Lake Superior.

Marine transportation costs have been addressed in Chapter 4. General comments about the impact that these costs can have on the supply market viability are discussed below.

Potential facility sites located on the navigable Lake Superior coastline where aggregate can be loaded directly from the source onto ships can add a significant cost advantage to competing inland sites that require some manner of overland transport to an intermodal transfer. These cost savings are available to offset some of the higher costs reviewed, such as labour and ancillary support systems. They may also compensate for higher shipping costs over what is assumed to be longer distances. The issue that will impact the present analysis on a site by site basis will concern the magnitude of the savings from the initial lake-side facility offset against the various higher costs.

Another factor which will impact the feasibility of an operation from a transportation standpoint is the concentration of demand. A typical aggregates extraction facility might produce about 1.5 million tonnes of crushed rock, which would fill about 56 vessels. Over the 37 week shipping season, therefore, the facility is transporting about 3 ships every 2 weeks. Although the product from the quarry is continuous, efficient delivery is discrete, and limited to a small number of units. A facility that develops the bulk of its demand in one or 2 large markets, can better maximize this supply line by ensuring that its deliveries are made in whole ship-loads and on a timely and frequent basis. By contrast, a facility that develops small markets in a number of different locations will be faced with either shipping partial ship-loads or making infrequent deliveries to particular markets. Servicing a variety of markets that are geographically diverse will be an economic challenge. Successful operations will likely rely on developing sufficient volume demand from one or 2 large markets so that they can maximize the efficiency of their transportation economics.

5.2.8 Overall Supply Conditions

Although many factors are necessary to assess the individual feasibility of any site, the overall assessment indicates that there are sufficiently positive supply-side factors to support a number of extraction facilities throughout the study area.

Three principal factors are reviewed in this analysis, including highway access, proximity to labour markets and proximity to business centres. Table 5-2 summarizes these 3 principal criteria for the 15 candidate areas. Six areas score positively in all 3 criteria, a further 6 areas score positively in at least 2 of the criteria and the remaining 2 areas score positively within only one criteria.

In general, the feasibility of establishing extraction facilities depends heavily on individual site factors, but that the likelihood of a successful operation is higher in 6 areas that are identified as scoring positively in all 3 criteria in Table 5-2.

Table 5-2: Assessment Criteria for Candidate Sites

	Proximity to Business Centres			
	Highway Access	**Within 100 km[1]**	**Within 200 km [2]**	**Positive Factors**
Goulais Bay	X	X	X	3
Batchawana Bay	X	X	X	3
Montreal River	X		X	2
Minnekona Point (Wawa)		X		2
Floatingheart Bay		X		1
Playter Harbour	X	X		2
Marathon	X	X		2
Steel (Bottle Point)	X	X		2
Terrace Bay	X	X		2
Plays Plat Bay	X	X	X	3
Nipigon Bay	X		X	2
Black Bay – St. Ignace			X	1
Dorion	X	X	X	3
Shuniah	X	X	X	3
Neebing	X	X	X	3

1. Site within 100 km of existing community with at least 4000 population.
2. Site within 200 km of community with at least 10 000 population.

Per tonne production costs at potential sites are influenced by 2 separate factors:

- Higher wage rates, greater distance from business centres, and from equipment maintenance and manufacturing facilities and greater infrastructure costs will only partially mitigate lower costs for land leases, remediation and licensing. Thus any

facility that locates in the study area likely faces production costs that are 20 to 40 percent higher than comparable facilities in southern Ontario;

- Particular facilities locating in sites that face extraordinary costs as discussed in this section (i.e., no road access, lack of proximity to labour markets or business centres, etc.) will face production costs that are higher still, perhaps in the order of 40 to 60 percent higher than comparable facilities in southern Ontario.

Recent f.o.b basis prices of crushed stone in Southern Ontario are in the order of $8.20 per tonne (Aggregate Producers Association of Ontario 1998). Crushed stone production in Ontario is a competitive market, and therefore the f.o.b. prices are seen to be a reasonable proxy for production costs plus normal rates of return.

Although the specific influences on costs for potential facilities in the study are will vary from site to site, as a working assumption in this analysis, it is assumed that costs will be roughly 50 percent higher than for comparable facilities in southern Ontario. Crushed stone prices, therefore, would be in the order of $12.30 per tonne f.o.b.

5.3 UNITED STATES MARKETS

5.3.1 General

This section reviews key factors affecting opportunities for the export of high quality crushed stone to the United States in general. Some markets for Lake Superior crushed stone may emerge within Canada, but potential opportunities in the United States are key to the feasibility of potential stone quarries within the study area.

5.3.2 Demand Factors for High Quality Crushed Stone

The analysis focuses on demand for high quality crushed stone, such as could be produced from the Lake Superior study area. The dense, hard and chemically inert aggregate is more valued for specific applications such as the paving of major roadways, because it meets higher quality specifications than limestone and dolostone aggregate found in many of the demand regions examined. These high quality aggregate products command higher market prices and are thus able to support the cost of transport to market where the sources are found further afield. Rock that can meet high quality specifications can also be used for lower specifications products if the financial opportunity exists.

Superpave

The Superpave system was developed in the late 1980s and early 1990s by the Strategic Highway Research Program of the National Research Board in order to determine why some asphalt mixtures used on road surfaces appeared to perform better under extreme temperature and load conditions than others, and to develop new standard specifications for high quality asphalt mixtures (United States Department of Transportation 1996). The Superpave program was transferred to the United States Federal Highway Administration in 1994.

The introduction of Superpave specifications to federal and state highway projects in the United States is having implications on the aggregates industry. Superpave specifications require high quality crushed stone mixtures. As Superpave is adapted by individual state Departments of Transportation, state-specific standards are developed, which tend to be adaptive to stone types that are locally available (Pit & Quarry, January 2000). Aggregate must be manufactured from durable rock types, but not necessarily granites or traprock. For example, in Minnesota, Superpave specifications allow for a certain amount of iron ore slag. The Superpave initiative is encouraging state Departments of Transporation to consider various stone sources in order to achieve higher durability and performance standards. Superpave, more than any other initiative, is creating more demand for high quality aggregate than has traditionally existed in the Great Lakes states.

Coarse Aggregate Pavement Specification

Increased incidence of premature rutting of heavy duty asphalt pavements in the United States and elsewhere has been experienced in recent years. There is a general agreement among asphalt paving technologists that the use of coarse aggregates in the binder and base courses will reduce the rutting of heavy duty-pavements. Several states, such as Michigan, are presently considering legislation that will introduce a wider array of applications where coarse aggregate pavement mixtures are required.

Coarse aggregate pavement mixtures will likely have a profound effect on aggregate demand. Although coarse aggregate mixtures do not specify igneous rock per se, they do require very durable rock in order to minimize fracturing and splintering of rock fragments in extreme weather situations. Not all currently used carbonate rock aggregate will meet quality requirements for the coarse aggregate and it is likely that some jurisdictions will move toward using crushed igneous rock. Increased movement toward coarse aggregate pavement mixtures will likely increase the longer term demand for crushed igneous rock.

New Highway Construction

Highway construction throughout the United States is presently getting a boost from Federal legislation. The Transportation Equity Act for the 21st Century (Public Law 105-178), passed in 1998, appropriated over $200 billion for new transportation projects throughout the United States, and it is expected to last through to 2003. At least $165 billion within the bill is directed toward highway and highway safety projects (Pit & Quarry, March 1999).

By contrast, the annual value of highway and street construction in the United States in 1997, according to the United States Census Bureau, Construction Census, was about $48.4 billion. The funds from the Transportation Equity Act that are being spent over a roughly 5 year period may provide up to a 70 percent increase in aggregate consumption.

The increase in highway construction has a direct impact on demand for aggregates. Some estimates suggest that overall aggregate demand (road bed and surfaces) is close to 100 000 tonnes per mile for a newly built 4-lane highway. More accurately (because it includes new construction and refurbishment), according to a relationship between United States Geological Survey data and United States Census Bureau spending data, demand for approximately 6300 tonnes of crushed stone is generated from each one million dollars in road construction.

Although the impact of the Transportation Equity Act will be of shorter term than the study period, it is still relevant, because it increases the overall level of stone demand through the medium term and contributes to the on-going depletion of available supply that will affect longer term availability.

Thus, the Transportation Equity Act may generate additional demand of up to 1 billion tonnes of crushed stone over a 5 year period. Assuming the Great Lake states receive their fair share of this spending allocation, demand generated by the Act would lead to about 320 million tonnes of additional crushed stone over a five year period, as the 1997 Economic Census estimates approximately 32 percent of total national highway, street, bridge and tunnel construction spending was within the 8 Great Lakes states.

5.3.3 Overview of the U.S. Crushed Stone Industry

In 1999 approximately 1.6 billion metric tonnes of crushed stone were consumed in the United States Of this, approximately 71 percent was limestone and dolostone – representing by far the majority. High quality stone such as granites and traprock captured about 15 percent and 8 percent of the market respectively. The remaining 6 percent was composed of sandstone and exotic stone such as quartzite, calcareous marble, slate and marble (United States Geological Survey 1999).

In many applications, other materials also compete with crushed stone, including blast furnace slag (from iron ore) and recycled cement and asphalt. Recycled materials have become more prevalent in many states as the refurbishments of old buildings and roadways increases, and as increased limitations and costs imposed on the use of landfills has made recycling these materials more economically viable.

In 1999 the United States Geological Survey (1999) forecasted that demand for crushed stone of all types over the following 20 years would be about 36.5 billion tonnes – roughly equivalent to the volume of stone produced in the United States during the entire 20th century.

Challenges and Opportunities

The demand for crushed stone is very closely related to construction of infrastructure, homes and other buildings. In turn, development of this nature is tied to existing population and to population growth, which in turn is increasingly concentrated in large urban centres.

Overland transportation costs play a significant role in the economics of crushed stone use in these development applications. The current survey of buyers in American demand markets indicates that transportation costs can typically be about $3.60 per tonne for every 20 km that the stone is hauled. Traditionally, this has meant that the most quarries have been located as close as possible to major urban centres where the demand is highest. Some of America's largest stone quarries are located within the urban envelope of large centres. Two of the largest 10 stone quarries in the United States, for example, are both within the urban envelope of Chicago.

Quarries that are presently located within urban areas are becoming depleted, and resources of stone within the urban areas are becoming inaccessible due to surface developments. Demand in many of these markets is increasingly turning further afield to source the crushed stone necessary for the highest quality applications.

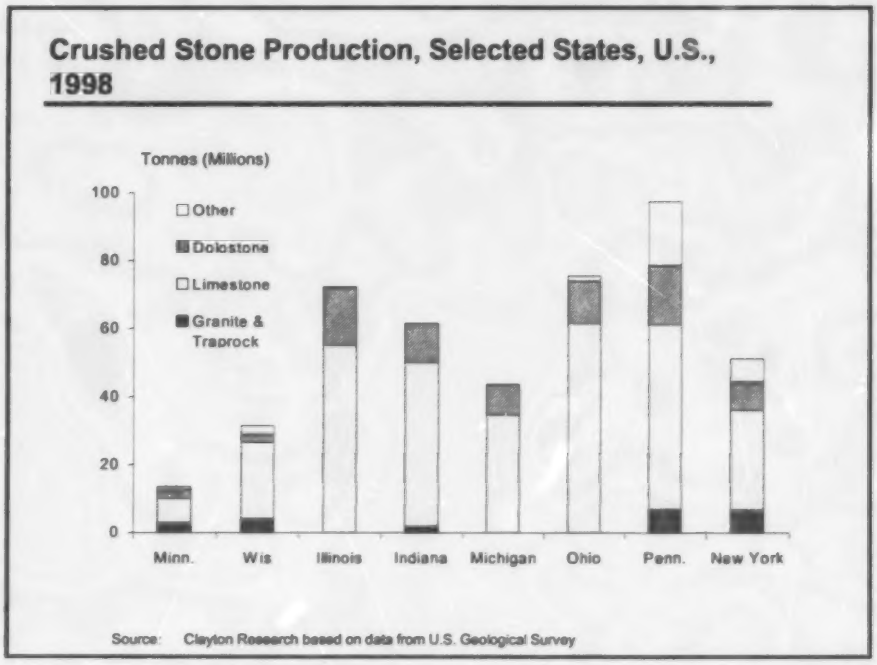
The degree to which local sources of stone are being depleted and replaced by materials from further afield is examined in the next section.

5.3.4 Stone Production in the Demand States

The metropolitan demand markets examined in this study are located around the Great Lakes and span 8 states. Geological conditions also vary across these states and influence the types of stone produced at local quarries.

Figure 5-1 illustrates the pattern of crushed stone extraction by rock type. The intent of this analysis is to illustrate the high dependence on limestone and dolostone in the demand market states. In total, these states produced about 440 million tonnes of crushed stone in 1998, of which 22 million tonnes (or about 5 percent) was granite or traprock. By comparison about 25 percent of United States wide production was granite and traprock.

Figure 5-1



With the exception of Minnesota and Wisconsin, there is nearly no production of granite and traprock from domestic quarries in the Midwest states. Production of these products is more prevalent in Pennsylvania and New York, but not in the proximity of the Great Lakes cities.

The quality of the limestone and dolostones extracted in proximity of the demand markets varies across the studied region.

Some of the highest demand for imported high quality stone comes from the South-Atlantic States, in particular Florida. In Florida there is no production of igneous rock such as granites and traprock. There is production of limestone, about 78 million tonnes in 1998, but the rock is generally too soft to meet Superpave specifications.

Notwithstanding this source of demand, transportation from Lake Superior sites to Florida is seen to be an uneconomical option over the study period due to the high cost of transportation.

5.3.5 Demand for High Quality Crushed Stone

A number of factors indicate that demand for imported stone in the Great Lakes urban markets will be rising through the next few decades.

High Quality Rock (granite and traprock)

- These markets have historically had very little production or use of high quality granite and traprock crushed stone;
- Historically, demand for high quality stone has been low, with most applications adapting to what stone is readily available;
- Some markets already rely to a small degree on high quality stone transported in from other states or from Ontario;
- Pressures in all markets to address asphalt quality in roadways, particularly issues of polishing and compacting, have increased the awareness of the need for high quality crushed stone in some applications.

Carbonate Rock (limestone and dolostone)

- Most crushed stone production in the demand markets studied is limestone and dolostone, although some markets have very little crushed stone production whatsoever within their local vicinity;
- In the United States Midwest, the limestone is suitable for many engineering applications where high quality stone is specified. Some of the limestone from the Midwest is considered acceptable for Superpave applications;
- All markets have sand and gravel operations, and these sources can substitute for high quality crushed stone in some applications;
- Proximity to the urban core is an important supply consideration. Many markets have relatively centrally located crushed stone producers, but as these become depleted greater supply constraints will emerge. The typical quarry lifespan is 25 to 50 years, and many of these urban operations have already operated for several decades.

The key to assessing the viability of potential high quality crushed rock extraction facilities within the Lake Superior coast study area is to consider the potential demand markets within the context of the transportation associated with getting the stone to those markets.

All major urban areas (at least 250 000 in population) located along the Great Lakes are considered potential markets in this analysis. This criteria allows the opportunity to transport the stone directly from the potential facility via ship or barge to a port in the demand market. The analysis focuses on potential needs in 14 large urban agglomerations located within 30 km of the navigable Great Lakes system. Ten of these markets are found in the United States and 4 in Ontario.

This section will outline supply and demand conditions in the 10 United States markets that may have an impact on ultimate demand for crushed stone extracted from the study area.

5.3.6 Minnesota and Wisconsin

Two port cities were examined in these states:

- Duluth-Superior - Located at the western end of Lake Superior, this port is closest to the supply markets on the north shore of the lake. Population in 1998 was 236 000 in Duluth-Superior;

- Green Bay - Located at the southern tip of Green Bay, along the west shore of Lake Michigan, the population in 1998 in this metropolitan area was about 560 000.

Supply of Crushed Stone

Favourable geological conditions in Minnesota yield the highest production of high quality crushed stone among any of the demand markets examined in this study. About 20 percent of recent crushed stone production in Minnesota has been granite or traprock. Within 40 km of Duluth-Superior there are 5 basalt quarries (United States Geological Survey, Mineral Resources On-Line Spatial Data). Most of the high quality crushed stone produced in Minnesota is in the north part of the state, but the major metropolitan area of Minneapolis-St. Paul presently imports all of its high quality granite stone from a large deposit in Stearns County, about 120 km away (Southwick et al. 2000). Minnesota Department of Transportation officials also report a high use of blast furnace slag in high quality asphalt. There is an abundance of slag available in Duluth.

Wisconsin is also well endowed with high quality igneous bedrock but not within the immediate proximity of Green Bay. Approximately 13 percent of crushed stone production in Wisconsin is from high quality granites and traprock. These deposits are principally located in the north part of the state, including Marionette and Florence counties in the northeast, which are approximately 100 to 200 km from Green Bay. There is some production in Shawano County, which is about 65 km from Green Bay. Another large source of igneous stone is a large ridge that runs through Iron, Ashland, Sawyer and Washburn counties in the northwest of the state. These quarries are closer in proximity to Duluth (about 120 km) and to Minneapolis-St. Paul (about 250 km).

Prices

Prices for high quality aggregate (granites and traprock) in Wisconsin are approximately $5.05 per tonne f.o.b – somewhat below local prices for carbonate rocks which are about $6.09. These prices are well below national average of $9.15 and $7.50 respectively. Prices in Minnesota are somewhat higher. Delivered prices will reflect the relative distances from the sources to the metropolitan area. In Green Bay, for example, where high quality stone is delivered between 100 and 200 km away, delivered prices are likely to be in the $27 to $32 range. In Duluth, the increased distances to sources, and competition from competing supplies (such as slag) mean delivered prices of approximately $14 to $19 per tonne.

Based on the transportation costs developed in Chapter 4, and the production costs enveloped in section 5.2.8, delivered prices in Green Bay would likely be in the $22 to $32 range (depending on the overland distance from the dock to the delivery site). Therefore it is possible that small volumes of imported stone could compete on a cost basis almost immediately. Over the next 10 to 15 years, however, prices of locally originated stone will rise modestly in response to the development of further supply constraints, at which point imported stone would likely develop a more substantial price position.

Growth

Recent population growth in Minnesota and Wisconsin has been about 0.9 percent and 0.8 percent per year respectively. However, this growth has not been reflected in Duluth-Superior which between 1990 and 1998 lost about 3500 people. Green Bay, by contrast, has grown at about 1.2 percent per year – capturing about 15 percent of all population growth in the State of Wisconsin.

Population projections prepared by the Census Bureau incorporate an optimistic long-term population growth in these states. Minnesota is expected to expand by about 15 percent over the next 25 years, adding about 680 000 new people. Wisconsin is predicted to grow by 10 percent over the same period, adding about 540 000 persons.

An expanding population implies increased need for crushed stone to support new building and highway construction.

Highway Construction

Annual spending on road construction in these 2 states is approximately US$2.7 billion according to the 1997 United States Economic Census. This represents about 4.2 percent of U.S. road construction spending. Winter climates and long distances between population centres in these states result in a higher rate of road construction per capita. The outlook for continued population growth implies continued efforts to develop new roadway projects and upgrade existing facilities.

Demand Feasibility

The overall demand potential for high quality crushed stone from Lake Superior in these centres is mixed. There likely will be limited potential to develop a market for Lake Superior crushed stone in Duluth (or points from Duluth such as Minneapolis-St. Paul). However, there is a medium to high potential to develop the Green Bay marketplace. Duluth has a substantial local supply of high

quality stone and slag, and recent growth patterns suggest that stone demand in general will remain modest. Green Bay, by contrast, has a positive growth profile and is serviced by some high quality stone within reasonable proximity. Imported stone from Lake Superior would likely have an opportunity to compete with these local sources.

Any demand that might emerge in Duluth would be at least 25 years in the future. The demand in Green Bay likely contains some niche markets that could be developed almost immediately and markets for larger volumes could emerge within the 10 to 25 year range.

5.3.7 Illinois and Indiana

Chicago-Gary is a large metropolitan agglomeration with numerous port facilities available for the importation of crushed stone. In total, the population of this combined metropolitan area was about 10.6 million in 1998.

Supply of Crushed Stone

Neither Illinois nor Indiana are well endowed with rock deposits yielding high quality crushed stone products. There was no production of high quality crushed stone in Illinois in 1998 and only minor production in Indiana (1.8 million tonnes – 3 percent of state-wide crushed stone production).

There is, however, considerable carbonate bedrock production in these states. Nearly 13 percent of all limestone and dolostone production in the United States is found in Illinois or Indiana. Moreover, 2 of the nation's 10 largest stone quarries are located within the Chicago-Gary urban area.

At present, local sources of crushed stone satisfy the local demand. There are 3 important emerging issues in Chicago-Gary, however, that will influence the outlook for the marketplace:

- Production from local quarries will abate in the decades to come. The largest mine in Thornton, likely has 50 years of production left, but the other quarry, in McCook, is already experiencing land use pressure and the quarry will likely end production over the next 10 to 15 years. There is low potential for further development of new local stone sources on lands that are not already developed for conflicting uses;

- Although Departments of Transportation in both Illinois and Indiana are satisfied with the characteristics of local limestone for quality asphalt applications, there is growing concern that carbonate rock in general is insufficient to obtain a high degree of friction control and to reduce the amount of surface polishing;

- Recent legislation in Illinois provides for greater responsibility by road contractors. Contractors who bid on highway projects will be required to monitor and maintain roadways for a period of 5 years. The implication of this is that contractors will look harder at the issue of using higher quality asphalt mixtures initially if it will control their long term costs.

Steel blast furnace slag from mills in Gary is also used in some asphalt applications. Slag use in road construction may not have the friction concerns that the carbonates do.

Prices

Prices for carbonate aggregate in Illinois are approximately $7.60 per tonne f.o.b. Indiana prices are about $6.70. These compare to the national average of $7.50. Delivered prices will reflect the relative distances from the sources to the metropolitan area. The availability of crushed stone in the locality of Chicago means that for many projects prices are about $11 to 13 per tonne. However, as local sources become depleted and Chicago looks further afield for aggregate these prices will rise.

Based on the transportation costs developed in Chapter 4, and the production costs developed in section 5.2.8, delivered prices for Lake Superior stone to the Chicago-Gary area would likely be in the $22 to $32 range (depending on the overland distance from the dock to the delivery site). Therefore, imported stone would have difficulty competing with stone from local sources purely on a cost basis. It is possible that small niche markets will be developed in the near term, where the imported stone competes on the basis of superior quality for high performance applications. A substantial volume market, however, is expected as local supply constraints emerge over the next 10 to 15 years, placing significant upward pressure on locally originated delivered prices.

Growth

Recent population growth in Illinois and Indiana has been, advancing at about 0.5 percent per year. The Chicago-Gary urban area is advancing at a rate of about 77 000 persons per year and recently has captured about 83 percent of growth across the 2 states. This recent growth in the urban area has led to more activity in both roadway construction and residential and non-residential construction.

Population projections prepared by the United States Census Bureau incorporate relatively optimistic long term population growth in these states. Illinois is set to expand by about 12 percent over the next 25 years – adding about 1.4 million persons to the state. Indiana is expecting growth in the 8 percent range, representing about 500 000 new persons.

Highway Construction

Annual spending on road construction in Illinois and Indiana is approximately US$4.3 billion according to the 1997 United States Economic Census. This represents about 8.6 percent of United States road construction spending. Road building budgets will continue to increase due to the demand created by the additional population growth over the next several decades.

Demand

The pressures on applications for higher quality stone are important in Chicago. There is considerable highway, street and bridge construction taking place, in part because of local population growth. High quality stone is not available either locally or within a reasonable vicinity, but there are indications that high quality crushed stone will be used for selected highway construction in the near future. Presently, imported stone will have difficulty competing with

local carbonate rocks on a cost basis, but as markets for high-quality applications develop and as limestone prices rise, there is significant potential for an imported stone market in Chicago over the next few decades for both high quality and routine quality applications.

There is likely an immediate demand for low volumes of high quality stone filling niche markets. Within the next 10 to 15 years demand for higher volumes of stone will occur as current local sources are depleted.

5.3.8 Michigan and Ohio

Five cities were examined in these states:

- Grand Rapids - Located about 65 km inland from the east shore of Lake Michigan (linked to port town of Macatawa), Grand Rapids is an important regional centre with a population in 1998 of just over 1 million;
- Saginaw-Flint - This agglomeration located in mid-east Michigan includes the large industrial centre Flint (population 440 000) and the port city of Saginaw (population 400 000);
- Detroit - Population 5 million, located on Lake St. Clair and the St. Clair River;
- Toledo - Population 610 000, located on Lake Erie; and
- Cleveland - Population 2.9 million, located on the south shore of Lake Erie

Supply of Crushed Stone

For the most part, neither Michigan nor Ohio are endowed with igneous rock formations from which high quality stone can be extracted. The western part of Michigan's Upper Peninsula has mixed igneous rock, but at present there are no extraction facilities and this area is a considerable distance from the population centres. Similarly, there are igneous rocks in the southern part of Ohio (Lawrence County) but no extraction is taking place. Both states engage in extraction of limestone and dolostone, and miscellaneous other rocks. Michigan and Ohio also rely on blast furnace slag to a small degree (approximately 2 million tonnes per year in Michigan) and imported high quality stone, mostly from Bruce Mines, Ontario on the North Channel of Lake Huron.

In 1998 approximately 43.7 million tonnes of crushed stone were produced in Michigan and 75.6 million tonnes in Ohio. Collectively, this represents about 8 percent of national crushed stone production.

Two of the country's 10 largest crushed stone extraction facilities are located within Michigan, both located in Presque Isle County, in the north-east portion of the Michigan mainland, 250 km from Saginaw and 400 km from Detroit. Crushed stone produced in Presque Isle County is transported to Detroit and other markets by ship, barge and train.

There is little or no crushed stone production in the vicinity of Grand Rapids, although there are numerous sand and gravel operations – which can compete with crushed stone use in

some applications. Grand Rapids and surrounding area rely on stone that is mined within the state and transported up to 300 km.

There are 2 minor crushed limestone operations in Saginaw-Flint, Michigan, and 2 more major quarries within 100 km: an E.C. Levy limestone operation in Huron County (about 110 km); and a R.E. Glancy limestone operation in Arenac County (70 km).

Detroit depends largely on 7 major limestone quarries for its crushed stone needs. Two quarries (an E.C. Levy operation and Michigan Foundation Quarry) are located within the urban boundary and the remaining 5 quarries are located in Monroe County (55 km south of the city). The large number of operations within reasonable proximity to such a large city ensures that delivered prices are competitive and that the supply of stone will be maintained through a 50 year time horizon.

Toledo, Ohio is located approximately 35 km from the same 5 quarries located in Monroe County, Michigan. In addition, there are 2 quarries within Toledo and 2 quarries located in nearby Ottawa County (approximately 50 km).

In Cleveland, there are 2 small crushed limestone operations and one sandstone operation within the urban limits. There are also numerous sand and gravel operations within Cleveland and nearby Akron, Ohio.

Prices

The abundant supply of crushed limestone in Michigan combined with relatively low quality product requirements is in part responsible for some of the lowest stone prices in the United States. Limestone prices in Michigan in 1998 were about $5.65 per tonne f.o.b, compared with a national average of about $7.50. Prices were higher in Ohio at $6.84 per tonne f.o.b., although still low by national standards.

Large supplies of stone in the Detroit area translates into relatively low delivered prices in the $10 to $13 per tonne range. Prices in Saginaw-Flint are likely in the $22 per tonne delivered range, and in Grand Rapids $25 to $30, or more. Delivered prices vary widely due to variation in supply, delivery conditions and other factors. Delivered stone prices are relatively low in both Toledo and Cleveland due to the proximity to stone sources – perhaps about $10 to $15 per tonne delivered.

Based on the transportation costs developed in Chapter 4, and the production costs developed in section 5.2.8, delivered prices in these markets would likely be in the $22 to $32 range (depending on the overland distance from the dock to the delivery site). The only market where imported stone priced in this range could compete on a price basis within the near term would be Grand Rapids. Other Michigan and Ohio centres enjoy relatively low prices and there would be little chance of developing more than small niche markets that could compete on the basis of quality.

Growth

Michigan and Ohio have experienced relatively slow growth in the recent past. Between 1995 and 2000 each state's population has grown by about 0.3 percent per year – about half the national

average. There has been a mixed population growth in the 5 port cities considered in this section. Grand Rapids, grew at about 1 percent per year, whereas Saginaw-Flint grew at about 0.1 percent. Detroit also grew advancing about 0.3 percent per year, during the 1990s, but nearby Toledo, Ohio, experienced modest declines through the same period. Modest growth, about 0.2 percent per year, occurred in Cleveland, Ohio.

The mixed, but generally modest, population growth in recent years in these study markets will lead to a mixed pattern in aggregate demand. Although high quality crushed stone is not as closely linked to population growth as other grades of aggregate, market softness due to slower population growth will have impacts in all the aggregate sectors.

Population projections prepared by the Census Bureau incorporate relatively modest long-term population growth in these states. Both Michigan and Ohio are predicted to expand by about 4 percent over the next 25 years. This implies growth of about 500 000 and 400 000 persons respectively. Modest population growth implies relatively modest increases in demand for crushed stone to support growth.

Highway Construction

Annual spending on road construction in Michigan and Ohio is approximately US$4.2 billion according to the 1997 U.S. Economic Census. This represents about 8.4 percent of U.S. road construction spending. The relatively muted population growth forecasts for Michigan and Ohio suggest modest roadway building budgets, but repair and upgrade work will continue to create market opportunities for aggregates for general and high quality aggregate.

Demand

Overall demand for these centres is mixed. There is considerable room for high quality imported crushed stone in the Grand Rapids market, from the perspective of price competition and existing supply conditions, but the overall market size remains relatively small. Another smaller market, Saginaw-Flint has less development opportunity.

There is a high potential to develop the Cleveland, Ohio market but only a moderate potential in Toledo.

The key to developing markets for imported high quality crushed stone in Michigan and Ohio remains the viability of penetrating the important Detroit marketplace. Detroit, remains well supplied with large local good quality carbonate rock and the supply appears well positioned to meet long term demand. Imported stone will have difficulty penetrating this market both from the perspective of price and from the perspective of supply. However, the lack of high quality stone in the Detroit market, and the existing reliance on some Canadian high quality stone, does imply an opportunity to compete in this market. The focus on coarse aggregate pavement mixtures and higher standards for Superpave asphalt mixtures will continue to create demand for high quality crushed stone.

There will likely be an almost immediate demand for high quality stone in Grand Rapids, although the limited size of that market limits the magnitude of this demand. Also within the 10 to 25 year horizon, reasonable demand will likely develop in Flint and also in Cleveland. By contrast, the local availability of supply in the key markets of Detroit and Toledo effectively means that

there is not likely to be more than limited niche market opportunities develop within the longer term 25 plus year horizon.

5.3.9 Pennsylvania and New York State

Three Great Lakes port cities were examined in Pennsylvania and New York:

- Erie, Pennsylvania - This metropolitan area had a population of about 445 000 persons in 1998 and is the only city with access to the Great Lakes;
- Buffalo and Niagara Falls, New York - These cities collectively have a population of about 1.15 million persons, and have access to the Great Lakes system through ports on the east end of Lake Erie and through the Niagara River;
- Rochester, New York - Population of just over 1 million persons in 1998. It is a port city located on the south shore of Lake Ontario.

Supply of Crushed Stone

Pennsylvania and New York state are well endowed with igneous rock formations and support a number of quarrying operations that produce high quality granite and traprock crushed stone. New York produces about 7 million tonnes of granite and traprock combined, about 15 percent of its total crushed stone production. Pennsylvania produces about the same quantity, representing about 7 percent of the state's total production. Collectively New York and Pennsylvania produce about one-tenth of all the high quality crushed stone in the United States.

The high quality igneous rock deposits and operations are concentrated in upper New York State and the extreme eastern counties of each state, significant distances from the studied population centres.

There are no significant crushed stone operators in or around the Erie metropolitan area. There are, however, a number of sand and gravel operators. Erie is about 250 km from the Harrisburg area of Pennsylvania which is a source of crushed granite. Erie is about 150 km from Buffalo.

In Buffalo, although there is no quarrying of high quality igneous rocks, there are 4 major limestone operators and several smaller operations along the Niagara Escarpment. The supply of stone within proximity of the urban area is expected to satisfy long term demand in the region. Buffalo is located about 450 km from the closest granite or traprock producers which are either in upper New York State (St. Lawrence county) or lower Pennsylvania. Crushed igneous rocks are produced in Westchester and Rockland Counties near New York City, but these sources are presently supplying a high eastern-seaboard demand and unmined deposits are becoming progressively scarce due to competing land development.

A similar situation exists in Rochester. There are 4 major limestone producers in the Rochester area — one local, 2 in Genesee County (within 50 km) and one in Wayne County (60 km). However higher quality stone is much more distant.

Prices

Prices for granites and traprock in New York State are approximately $11.90 per tonne f.o.b – somewhat above prices for limestone which sells for about $8.62. These prices are above national average of $9.15 and $7.50 respectively. Prices in Pennsylvania are somewhat more moderate. Delivered prices will reflect the relative distances from the sources to the metropolitan area. In Erie, where even limestone is delivered long distances, buyers may face prices in the $20 to $30 range. By contrast, delivered prices in Buffalo-Niagara Falls and Rochester will reflect the proximity and number of producers in the market, and will likely be in the $10 to $15 range.

Based on the transportation costs developed in Chapter 4, and the production costs developed in section 5.2.8, delivered prices for high quality crushed rock to points in Buffalo or Niagara Falls would likely be in the $22 to $32 range and to Rochester (which involves navigating the Welland Cannal) about $25 to $35 range (depending on the overland distance from the dock to the delivery site). It is possible that imported stone could compete on a cost basis almost immediately in Erie, but the remaining markets hold little potential for meaningful competition for imported stone over the medium term horizon.

Growth

Recent population growth in New York State and Pennsylvania has been sluggish. In the period since 1995, New York State's population has be virtually constant and Pennsylvania's has grown about 0.2 percent per year. Population in both Erie and Buffalo showed declines through most of the 1990s – Buffalo dropping by as much as 5000 persons per year. Rochester has seen modest population growth.

Population projections prepared by the Census Bureau incorporate a relatively muted picture of long-term population growth in these states. The estimates suggest that Pennsylvania is set to expand by about 4 percent, or about 480 000 persons, over the next 25 years. New York State is set for somewhat better growth expanding by an expected 9 percent or 1.68 million people.

Highway Construction

Annual spending on road construction in these 2 states is approximately $5.2 billion according to the 1997 United States Economic Census. This represents about 11 percent of United States road construction spending. Slower population growth suggests that less of the national housing budget will be directed to these states in the long term. This will have an impact on stone demand.

Demand

The demand for imported high quality stone in Erie, Buffalo and Rochester is mixed. None of the markets currently have ready access to high quality stone in spite of its abundance within their respective states. Buffalo and Rochester have abundant supplies of carbonate rock and few supply constraints for this product are likely to emerge, particularly under the relatively slow growth scenario expected over the next few decades. In Erie, the market is likely stronger due to the lack of supply of both high and medium quality stone products. Imported stone is likely to be positioned to compete on a cost basis in Erie but it remains a relatively small market with limited growth prospects.

There is immediate demand for imported stone in Erie although this is a small marketplace. The local supply of carbonate aggregate in and around Buffalo suggests that there will be low demand for imported stone in the near to long term. In Rochester, volume demand for imported stone could develop in the 10 to 25 year horizon. Opportunities for marketing high quality crushed stone in these cities will be limited to the niche applications for high quality materials.

5.4 ONTARIO MARKETS

5.4.1 General

In addition to the potential to develop specialized export markets to population centres in the Great Lakes States of the United States, there is also a potential for developing markets within Canada. This section of the report will explore previously published information on supply and demand conditions for crushed stone in Canadian population centres with access to Great Lakes ports.

According to the 1992 State of the Resource Study (Planning Initiatives Limited 1992), the major population centres of southern Ontario along the Great Lakes face a variety of key medium term supply constraints with respect to aggregates in general and crushed stone in particular. Drawing largely from the analysis presented in this report, and supplementing updated information where possible, a review of supply and demand conditions in major population centres in Ontario along the Great Lakes is presented. This information is in the context of potential demand for high quality crushed stone transported from the candidate areas along the Lake Superior coast.

5.4.2 Sarnia-Windsor-Chatham Market Area

The Sarnia-Windsor-Chatham market area, encompassing 3 counties in the southwestern portion of the province, had a 1996 census population of about 588 000. The area experienced moderate growth of about 23 000 persons (0.75 percent per year) in the preceding 5 years.

According to the State of the Resource Study, this market area is relatively well endowed with crushed stone extraction facilities and produces on average about 2.1 million tonnes per year. Crushed stone extraction represents about 64 percent of total aggregates extraction in the area by tonnage. The majority of the crushed stone consumed in this market area originates from quarries in the Amherstburg area – about 25 km from Windsor (279 000 population in 1996) and about 300 km from Sarnia (87 000 population).

This market area also imports stone. According to the State of the Resource Study, the local production tends to be deficient in higher quality course aggregates suitable for road building. As a result, the area's shortfall is met by imports from sources in the United States (about 65 percent of imports) and other parts of Ontario, particularly stone from Manitoulin Island (about 25 percent of imports). A network of docking facilities for handling the aggregate materials moved by marine vessels has been developed at various ports along the Lake Huron, St. Claire River, Detroit River and Lake Erie. In addition to marine imports, this area also receives stone transported over land from other points in Ontario, particularly Lobo Township (about 80 km from Sarnia) and Wingham (about 160 km from Sarnia).

In total, the State of the Resource study expected that about 2.2 million tonnes were transported by water into this market area and a further 1.3 million were transported by land. By 1992 the importation of stone was an accelerating trend, so it is likely that the continued supply constraints in local production and moderate population growth since those data were compiled may have increased these quantities somewhat. A trend to increased stone importation is also due to the lack of high quality course aggregate suitable for road construction within the local area.

Expectations are for faster growth than was in evidence over the period captured by the State of the Resource Study. Recent Ontario Ministry of Finance forecasts (Ontario Ministry of Finance 2000), for example, expect that growth in Essex County, a major component of this market area, will accelerate to about 3840 persons per year in the 1996-2021 period in comparison to about 3511 persons per year in the decade prior to 1996. This growth acceleration suggests that the shortages of construction and road construction aggregate, and particularly high quality stone, identified in the 1992 study have likely become more acute in the years since and are likely to become more so in the immediate future.

Because of the high reliance on crushed stone that is transported medium to long distances to this market area, delivered prices for high quality stone are relatively high -approximately $20 to $30 per tonne. The market is currently able to satisfy its demand for high grade stone from imported dolostone, primarily from Manitoulin Island. The potential of developing a market for high quality rock from Lake Superior, therefore, is limited both from the perspective of competing product, and by the limited size of the Sarnia-Windsor-Chatham market.

Based on the transportation costs developed in Chapter 4, and the production costs developed in section 5.2.9, delivered prices at Sarnia would likely be in the $18 - $28 range (depending on the overland distance from the dock to the delivery site). Therefore it is possible that small volumes of imported stone could compete on a cost basis almost immediately. There do not appear to be any new issues affecting the current shortage situation in the Windsor-Sarnia area and therefore it is likely that there will be moderate upward pressure on local prices over the medium term. These conditions will limit the ability of Lake Superior stone to compete in this market for the foreseeable future.

5.4.3 Brantford-Hamilton-Niagara Market Area

The Brantford-Hamilton-Niagara market area contains a large population base in Ontario and has access to Lake Ontario, the Niagara River, Welland Canal and Lake Erie. In 1996 this market area represented just under one million persons, and had experienced a moderate pace of growth through the first half of the 1990s, amounting to about 30 000 between 1991 and 1996, or 0.6 percent per year.

Crushed stone production in this market area represents the majority of aggregate extraction. On average about 9.2 million tonnes of crushed stone is produced in the area out of total aggregate extraction of approximately 12.1 million tonnes per year. Most of the crushed stone extraction is dolostone from quarries along the Niagara Escarpment. There is a relatively low reliance on high quality stone at present.

In spite of its high level of production, this market area is a net importer of aggregates in general, mostly due to a few million tonnes of aggregates imported from the sources around

Kitchener-Waterloo and Cambridge (about 70 km from Hamilton), Oxford County (90 km from Hamilton) and Milton (about 40 km).

Evidence from recent projections of population growth produced by Ontario Ministry of Finance suggest that the patterns of growth that existed through the period examined by the State of the Resource Study are likely to continue in the near term future. The Ministry expects that growth in the Hamilton Wentworth and Niagara Regions, for example, will slow slightly to about 5300 persons per year through to 2021 from about 7880 persons per year in the decade leading up to 1996.

Delivered prices for stone in this marketplace are influenced by the relative distances between local quarries and demand sites, the degree of reliance on imported stone and import distances. Because reliance on imported material is relatively low at present, and the import distances are not great, delivered stone prices in this market range from approximately $11 to $21 per tonne. Imported high quality rock from Lake Superior, that would be priced in the $24 to $34 range, will likely have difficulty competing in this area due to price and demand factors.

5.4.4 Greater Toronto Area

The Greater Toronto Area (GTA) is the heart of southern Ontario from the perspectives of economic activity, growth potential, population concentrations and recent population growth. The GTA, as approximated by the aggregation of 4 suburban regions (York, Peel, Halton and Durham) and the City of Toronto, had a 1996 population of about 4.6 million persons. The area expanded at 1.8 percent per year between 1991 and 1996, adding nearly 400 000 persons over the period. Estimates of growth since 1996 suggest that this rate has actually increased as the GTA absorbs the bulk of the economic growth that has taken place in Ontario in the late 1990s. Recent estimates and projections from the Ontario Ministry of Finance, for example, expect that population growth in the GTA will average about 88 000 persons per year through to 2021; about the same as in the decade leading up to 1996.

As with other large metropolitan areas, the GTA experiences competing development and land use for lands that are presently or potentially suitable for aggregate extraction. At present, most of the aggregate extraction facilities are located in the fringes of the urban area; often up to 60 or 70 km from the centre of the City of Toronto. Moreover, although sand and gravel pits are located throughout the suburban counties (where much of the residential, non-residential and commercial/industrial development is also taking place) quarries are all located in the northwest making transportation distances to the core and the eastern parts of the GTA significant. Some of the demand in the northern and eastern portions of the GTA is being supplied by relatively new quarry developments in the Lake Simcoe area.

Production of crushed stone in the GTA averaged about 14 million tonnes in the late 1980s, but had exhibited a sharp downward trend through the period. Crushed stone represents about 35 percent of total aggregates extracted within the GTA market area and the proportion of crushed stone is increasing.

Local production in the GTA falls well short of local needs both in terms of quality and quantity of aggregate. It is estimated that local production of crushed stone accounts for about 50 percent of local consumption. These ratios imply that there are acute shortages of locally produced stone to satisfy present and projected growth in the GTA. There is no production of high quality quarried stone in the GTA.

Stone and other aggregates that are transported into the GTA come from sources at various distances. The 3 largest import sources are all contiguous to the GTA and to the north and east. Northumberland, Simcoe and Victoria counties collectively contribute about 70 percent of stone that is transported into the GTA according to the State of the Resource Study. Stone from these sources is generally shipped to destinations in the east end of the GTA in Durham Region and to a lesser extent York Region. Typical travel distances for these overland routes are between 90 and 120 km.

The west end of the GTA, where most of the GTA's stone production takes place, is relatively self sufficient at present, although quarry sites that are not seen to be in conflict with other development uses are becoming rare. Some stone is imported into the western portion of the GTA from Simcoe County and from Hamilton-Wentworth.

Due to the size of the GTA and the diverging patterns of aggregate production between the east and the west, delivered prices vary considerably depending on the location of the demand. On average, prices are probably about $15 to $25 per tonne and are likely to rise as greater shortages emerge. Costs for high quality crushed stone are in the order of $30 to $35 per tonne, although this material tends to be consumed in relatively modest amounts. The higher cost for this material is due, at least in part, to transportation distances.

Based on the transportation costs developed in Chapter 4, and the production costs developed in section 5.2.8, delivered prices of Lake Superior stone delivered to the GTA would likely be in the $26 to $36 range (depending on the overland distance from the dock to the delivery site). Only limited amounts of high quality crushed stone could compete with existing sources at present. Over the next 10 to 15 years, however, delivered prices in the GTA will rise due to continued shortages of licensed quarries within the GTA and the need to source imports from further afield. The probable rise in prices would improve the feasibility of importing stone from Lake Superior.

Very little stone at present is imported into the GTA by marine vessels. One company, Lafarge, has a pier at the Port of Toronto and imports relatively small amounts of stone and other aggregates from points on the Great Lakes. The future of this particular dock is in question as conflicting development plans are in place for the Port that may not include any opportunity for intermodal aggregate transfers.

Two factors suggest that there is a reasonable chance of developing a market in the GTA for high quality crushed stone from Lake Superior:

- Local supplies of many types of aggregate are in significant short supply compared to the on-going demand and supplies are likely to be more constrained in the immediate future as development increases;

- The market is large enough to support bulk shipments of crushed stone in the quantities that would help to make such a transaction feasible.

The lack of available port facilities within reasonable proximity of the core of the GTA, however, is a mitigating factor. Crushed stone transported by ship to a port outlying the core demand area would require lengthy overland transport and this adds to the delivered prices of the

aggregate. The lack of central port facilities would jeopardize the competitiveness of marine-transported stone vis-à-vis imported stone transported by truck from neighbouring counties north of the GTA.

5.4.5 Other Markets in Southern Ontario

Other markets in southern Ontario also represent reasonable population bases and also have a demand for crushed stone and other aggregates, but are not within reasonable proximity of Great Lakes ports.

For example, in the Ottawa market (about 90 km inland from ports in Cornwall), a metropolitan market with a population of about one million persons and considerable growth potential, local crushed stone production is sufficient to meet local needs. The State of the Resource Study identified about a half million tonnes of crushed stone per year that was surplus to local needs and was exported to areas in the Province of Quebec.

Similarly, the Kitchener-Waterloo-Cambridge market (about 60 km inland from the Port of Hamilton and 90 km inland from ports on Lake Erie), which was about a collective 400 000 persons in 1996, produces more aggregates in total than it requires for its local consumption. On net about 4 million tonnes per year of aggregate is shipped from this area to neighbouring markets, particularly into Brantford and Hamilton.

Also, in the London market (60 to 80 km from Lake Huron and 30 km from Port Stanley on Lake Erie), which was about 410 000 persons in 1996, there is no production of crushed stone locally. An adequate supply of sand and gravel resources in the local market assuage the demand for aggregates in general. Crushed stone production in other counties would offset any demand that might arise for additional imported crushed stone.

5.5 IMPLICATIONS ON STONE DEMAND

The feasibility of developing demand markets in several metropolitan areas with access to the Great Lakes has been examined on the basis of a number of key criteria, including:

- Existence and proximity of existing stone quarries to the metropolitan area;
- Availability of high quality stone both in the state and within reasonable proximity of the metro area;
- The general timetable on which any demand for imported stone might develop, based on the size of availability of supply and the expected lifespan of existing resources;
- The overall market size in terms of population;
- The anticipated population growth, based on United States Census Bureau or Statistics Canada projections of population growth.

Table 5-3 illustrates the impact of each of these key criteria on the overall assessment of demand. The chart that is presented summarizes overall assessment as an ordinal function of each demand market's score in each criteria. Although this analysis is simply tool to summarize the impact of the assessment criteria, it does provide some important conclusions.

Table 5-3: Assessment Criteria for Demand Markets

	Proximity of Stone Quarries	Available High Quality Stone	Timetable for Demand Emergence[a]	Market Population Size	Anticipated Population Growth[b]	Overall Assessment (Ordinal Sum)
Chicago-Gary	1	3	3	3	3	13
Greater Toronto Area	3	2	2	3	3	13
Grand Rapids	3	3	3	2	1	12
Cleveland	2	3	2	3	1	11
Erie	3	3	3	1	1	11
Rochester	2	3	2	2	2	11
Green Bay	2	2	2	1	3	10
Sarnia-Windsor-Chatham	3	3	2	1	1	10
Saginaw-Flint	2	3	2	1	1	9
Detroit	1	3	1	3	1	9
Buffalo-Niagara	1	3	1	2	2	9
Niagara-Hamilton	1	2	1	3	2	9
Duluth-Superior	1	2	1	1	3	8
Toledo	1	3	1	1	1	7

3 = Conditions supportive of high demand for imported high quality stone
2 = Conditions supportive of medium demand for imported high quality stone
1 = Conditions supportive of low demand for imported high quality stone

a. In this case, 3=0-10 years for demand to emerge; 2=10-25 years; and 1=25+ years
b. State-wide population growth forecast, 2000-2025

- The most attractive markets for potentially developing demand for imported high quality stone are the Chicago-Gary and the Greater Toronto metropolitan areas. Chicago-Gary is the largest in the study area (over 10 million in population) and the GTA the third largest (approximately 5 million). In Chicago-Gary there are currently stone supplies in close proximity but there are signs of emerging supply concerns in the next decade. The GTA, by contrast, has a relatively strong (and expanding) reliance on imported stone, which has an effect on delivered prices. There is also the potential to develop specialized markets for higher quality rock, which, by and large, are not part of present consumption in either Chicago or the GTA.

- There are 4 other markets that appear to show reasonable potential for the development of imported high quality stone demand. These include Grand Rapids, Cleveland, Erie and Rochester. However, most of these markets (with the exception of Cleveland) are relatively small at present (1 million or smaller in population) and are not expected to expand very rapidly in the United States Census Bureau projections. Although it is expected that crushed stone markets could be developed in these areas, development would likely be

smaller and occur further in the future. In Section 5.2.7 it is suggested that potential Lake Superior facilities should develop concentrated demand markets in order to optimize their delivery economics. Thus these moderate sized centres may not be the most suitable within that context.

- The remaining centres in Table 5-3 appear to have limited potential for niche high quality markets. The largest market among these is Detroit (about 5 million). Strong local supply conditions suggest that the opportunities for imported stone to compete on a price and volume basis would, at best, be decades away.

The study also identified an increase in consumption demand for crushed stone by the year 2010 of approximately 12 million tonnes per year – 9 million tonnes of which is expected in the GTA alone. In the GTA, local production of stone is expected to continue declining as land development conflicts continue to put a strain on extraction facilities. Thus the reliance on imported stone from outside of the GTA will likely increase in excess of 9 million tonnes per year.

The GTA stands as the only feasible area of all the population centres in southern Ontario, to develop a market for imported high quality stone from the candidate sites on Lake Superior.

Over the next few decades a number of factors will place upward pressure on the delivered prices of crushed stone in the GTA, including the continuing exhaustion of production capacities within the local area, the importation of stone from greater distances overland and the increased market for higher quality stone. These factors are expected to foster a feasible market for Lake Superior stone within the next 10 to 15 years.

6.0 Aggregate Resource Development Potential

6.1 GENERAL

The current study was focussed on one fundamental question – *Is it feasible to mine high quality aggregate in the Lake Superior area for sale in central Canada and the United States?*

The study has examined the potential resources located along the Lake Superior shore, tested the rocks to obtain an assessment of the physical quality of the materials, examined the potential to transport the materials by ship or barge, examined the basic infrastructure required to establish the operation, identified potential receiving ports in the Great Lakes, examined potential markets, determined the approximate costs for shipping and estimated the current sale prices for aggregate in the market areas.

The factors noted above are key elements of the analysis of any potential aggregate resource assessment. They yield an overall picture of the potential to extract, transport and sell aggregate from the Lake Superior area.

The establishment of an actual aggregate operation on Lake Superior will involve the analysis of a large number of detailed factors that relate to the specific undertaking. Many of the

factors discussed in this report will have to be addressed in detail. For example, several candidate areas contain large intrusive geological units which contain uniform high quality rocks. The rock at any chosen site will have to be mapped, drilled, tested and perhaps subjected to production testing before one can say that the actual property will meet requirements. Similarly, several areas of coastline have been identified which have generally deep water approaches and protected anchorages. Detailed surveys will be required to establish the feasibility and costs of constructing the required port facilities. General market areas and trends have been identified. Further study will be required to identify completion specific potential product types and customers.

The final determination as to the viability of a particular business undertaking will involve the sum of all of the advantages and disadvantages of the undertaking, and the potential to compete against existing supplies and products. Many factors in the analysis can be quantified and subjected to detailed comparison; however, judgment, experience and business acumen are always ingredients of a successful undertaking.

The current analysis has focused on the higher quality aggregate materials. Those materials are the most difficult to manufacture, command the highest prices and are judged to be the most likely product to be exported on a commercial basis. There may be other rocks in the Lake Superior area which are capable of producing marketable products and there may be other products which provide an opportunity. The candidate areas identified in the study were chosen on the basis of available information and current experience with similar rocks at other locations in the province; they represent the highest probability of producing high quality aggregate.

6.2 HIGH QUALITY RESOURCES

The candidate resource area selection procedure used in this study involved the application of geology and recent aggregate testing experience to focus on prime bedrock resources. Rock types known to be variable or to have other quality concerns were excluded from the study. Selected resource areas were examined in the field and laboratory testing was conducted to evaluate aggregate quality.

The candidate resource areas fall into 2 broad bedrock types – granites (including diorite, migmatite, tonalite, and syenite) and diabases (including gabbro). Both rock types are consistent and durable, and both have been used in high quality aggregate applications in other parts of Ontario. Field and laboratory data obtained during this study indicate that 10 of the 15 candidate areas have potential to produce high quality aggregates (Table 6-1). The remaining 5 areas have variable potential due to a variety of geologic concerns, including grain size, and degree of metamorphism and weathering. Subsequent investigations of these rocks may reveal that high quality bedrock resources exist at specific locations within these areas.

Large quantities of bedrock resources are potentially available along the north shore of Lake Superior. An area of 1 km^2 within a consistent bedrock unit extending to 25 m depth has the potential of producing more than 50 million tonnes of aggregate. Preliminary estimates indicate that at least 10 of the candidate areas have potential to support quarry operations in excess of this size.

In summary, numerous sites exist along the north shore of Lake Superior that potentially contain large resources of high quality bedrock aggregate.

6.3 TRANSPORTATION POTENTIAL

Four of the 15 candidate resource areas (1, 2, 14 and 15) are located close to existing shipping ports at Sault Ste. Marie and Thunder Bay. Depending on potential quarry locations, staged transport of aggregate to an existing port, using secondary marine or overland transport vehicles, may be necessary within these areas. Distances between existing ports and the other candidate areas studied are relatively large and staged transport will significantly increase the cost of the product.

The potential to develop new shipping facilities, based on factors such as offshore water depth and shoreline conditions, was considered in Section 4.3.3 and is summarized in Table 6-1. Nine of the 15 candidate areas are considered to have moderate or high potential to develop new aggregate shipping facilities. In most of these cases, it is possible that docking facilities could be constructed close enough to the resource to permit direct loading of aggregate onto ships. Such a situation has obvious economic advantages. Hydrographic information reviewed during the study indicates that offshore water depths for candidate areas 2, 6 and 13 are probably too shallow or restricted to permit ship access. It is possible that shallow draft vessels, such as partly loaded ships or barges, could be accommodated or that deeper water access could be constructed in some of these areas. Based on draft requirements for loaded ships there are many existing ports on the Great Lakes, both in Canada and the United States, which are capable of receiving aggregates by water.

All but 4 of the candidate areas have access to major highways. In addition, railway lines cross 7 of the 15 areas. Main railway lines may be close enough to potential quarry sites to permit spur-line connections. Alternatively, trucking to railway loading areas may be possible from some sites.

6.4 DEMAND

The current trend toward "Superpave" designs for major roadway projects is already creating a "niche" market for high quality aggregate. Some areas already specify igneous or metamorphic rock types for Superpave type projects and other jurisdictions may follow this trend. Several areas, notably Detroit, are currently importing this type of aggregate in spite of an abundance of locally manufactured limestone/dolostone aggregate. The demand for this high quality aggregate is expected to increase in the next few years as approved infrastructure projects are built. It is probable that more contractors and highway officials will specify high quality igneous and metamorphic rocks for pavement use due to their superior durability and skid resistance over locally produced limestone and dolostone aggregates.

The market for high quality aggregates will continue indefinitely and volumes will probably increase slowly, but this niche market will likely remain a relatively small proportion of overall aggregate consumption. It is also possible that additional specification-dependent niche markets may be identified and developed. Diabases, for example, have a high specific gravity and are commonly suitable for railway ballast. Diabases have also been used for the manufacture of rock wool insulation.

A large proportion of the aggregate tonnages consumed comprise concrete aggregates (redimix concrete, structural concrete, blocks, etc.), common grades of asphalt aggregates (for base

TABLE 6-1: SUMMARY OF CANDIDATE RESOURCE AREA CHARACTERISTICS PHYSICAL EVALUATION AND ASSESSMENT OF BEDROCK AGGREGATE POTENTIAL NORTH SHORE OF LAKE SUPERIOR

Candidate Reource Area No.	Aggregate Resource Potential					Transportation Factors								Economics Supply Factors	
	Principal Rock Type	Quality Potential		Quarry Size Potential		Distance to Port (approximate km, by water)		New Shipping Dock Development Potential				Highway Access	Railway Access	Within 100 km of pop. 4000	Within 200 km of pop. 10 000
		High	Variable	>50 Mt	<50 Mt	Sault Ste. Marie	Thunder Bay	High	Moderate	Low	Shallow Water				
1	Diorite	•		•		20	440		•			•		•	•
2	Granite	•		•		75	410			•	•	•		•	•
3	Migmatite		•		•	100	370		•			•			•
4	Tonalite	•		•		200	340			•				•	
5	Tonalite	•		•		200	300			•				•	
6	Granite	•			•	320	230			•	•			•	
7	Syenite		•	•		340	210	•				•	•	•	
8	Gabbro		•		•	350	190		•			•	•	•	
9	Granite	•		•		370	180		•			•	•	•	
10	Granite		•	•		400	150	•				•	•	•	•
11	Diabase	•		•		450	170		•			•	•		•
12	Diabase		•	•		430	150		•						•
13	Diabase	•			•	450	100			•	•	•	•	•	•
14	Diabase/Granite	•		•		450	30			•		•	•	•	•
15	Diabase	•			•	460	10		•			•		•	•

courses, secondary roadways and general paving), granular materials (road bases, gravel roads, parking lots, etc.) and a variety of non-specification or specialty uses. The high quality resources from the Lake Superior area are capable of manufacturing many of these high volume products, but they would have to compete directly with local sources within, and closer to, the existing market areas. Local sand and gravel or limestone/dolostone sources are commonly cheaper to operate and produce an acceptable and familiar product. The Lake Superior materials do not enjoy any specification advantage for these products and price would be the most important consideration in this portion of the aggregates market. It should also be recognized that many of the granular and non-specification products sell at very low rates (in the order of $5 or less, per tonne, f.o.b. the source) and it is unlikely that prices will rise sufficiently to allow Lake Superior stone to complete in this portion of the market.

Future developments in selected local markets may allow for a significantly larger penetration of marine-based aggregate sources from Lake Superior. Several market areas, notably Chicago, are predicted to have general shortages of aggregate in the next 10 to 15 years due to the depletion of existing sources in the urban area and the need to develop replacement sources at greater distances outside the city. It will be possible to land marine-based aggregates within the central part of these urban areas and the increase in land based transportation costs as new more distant sources come on stream may off-set the costs of marine transport. This, in turn, will provide an opportunity to develop a broader market base.

6.5 LAND USE, LICENSING AND ENVIRONMENTAL FACTORS

Land use and environmental factors are becoming a progressively greater challenge for planning bodies, aggregate operators and local inhabitants in populated areas affected by aggregate operations.

Aggregate operations must compete closely for land in urban areas. Potential aggregate resource lands are also attractive sites for housing, commercial and industrial uses; competition for these lands is often fierce. Rural areas outside urban areas, which have been traditional locations for pits and quarries, are attractive settings for county estates and hobby farms. The competition for land commonly escalates land prices and results in the fragmentation of land holdings.

The competition for land use also results in an increased focus on environmental factors associated with aggregate operations such as noise, vibration, dust, flora, fauna, surface water and ground water. Costs for monitoring and mitigating effects on these concerns have become significant in recent years. The focus on these environmental factors is commonly traced to having different land uses in close proximity. Land use pressures and costs necessitate that differing, and often conflicting, land uses are located in the same area.

Transportation of aggregates from a pit or quarry is usually achieved by truck transport. Heavy truck transport in urban areas has been, and will continue to be, a major concern for aggregate operations and affected citizens. Mitigating the effects of heavy truck traffic is difficult, and in many cases, impossible; truck transportation of aggregate will continue to be a major concern.

The need to address all of the land use and environmental factors in a proposed aggregate operation results in significant cost and delays in licensing new operations. The need to meet and exceed regulatory requirements, and the need to mitigate local impacts has substantially increased operational costs of aggregate operations and has significantly altered the "risk" element for obtaining new licences.

Developing an aggregate resource in the Lake Superior area offers potential relief from a number of the land use, licensing and environmental concerns experienced in the more populated areas of the Great Lakes.

Many of the Candidate Areas discussed in Chapter 3.0 are sparcely populated or unpopulated. Land use pressures are expected to be less severe in most areas, and few areas will experience the intensity of land use pressure experienced in southern Ontario. The cost of land in most areas will be negligible; much of the land is owned by the Crown and potentially available for permit. Many of the candidate areas contain numerous alternative sites, so it may be possible to avoid significant concerns.

Similarly, it may be possible to avoid many environmental concerns in the Lake Superior area. Firstly, there are many alternative areas potentially available for possible development, and secondly, many areas contain large areas of bare rock which contain limited flora and fauna. Thus, there is a higher potential to avoid or limit environmental disturbance.

Local transportation of aggregate by truck can be eliminated by developing the facility close to the shipment facility and employing conveyors directly to the ship. Some trucking will be necessary from the receiving port facility to the customer, but most port facilities are located in industrial/commercial areas away from residential neighbourhoods.

The overall advantage of the factors noted above is that a Lake Superior site could substantially reduce the "risk factor" of a new operation by allowing a greater freedom to avoid land use and environmental concerns. These concerns do not have an identifiable cost, but they are significant concern for any producer contemplating a new aggregate operation.

6.6 VIABILITY

The overall viability of establishing and maintaining an aggregate extraction operation in the Lake Superior area will ultimately be the sum of 2 major cost factors; the cost to produce the aggregate material and the cost to move the material to the consumer.

The cost to produce a tonne of aggregate is often a closely guarded secret amongst industry workers; however, the average sale price of granite or traprock f.o.b. at the source is $9.15 in the United States. This number is assumed to include acquisition, extraction, processing, environmental and licensing costs, plus profit.

Similarly, it will cost approximately $11/per tonne to ship the granite/traprock from eastern Lake Superior to any of the Great Lakes ports (Table 4-2). Additional ground transportation costs may be incurred in moving the aggregate from the dock to the customer. Thus, it is reasonable to conclude that a tonne of high quality aggregate could be produced and shipped from Lake Superior

to a customer within a reasonable trucking distance of a Great Lakes port for in the order of $25 to $30 per tonne.

Prices of high quality aggregate are currently in this price range in Green Bay, Grand Rapids, Erie and Toronto, and other areas such as Chicago are predicted to see similar prices in the next 10 to 15 years.

In summary, a preliminary estimate indicates that Lake Superior aggregate may be produced and shipped to several Great Lakes ports for costs similar to current selling prices.

7.0 Conclusions

The current study was commissioned to address one fundamental question – Is it feasible to mine high quality aggregate in the Lake Superior area for sale in central Canada and the United States?

The study has: 1) reviewed the general geology of potential resource rocks in the area; 2) conducted selective quality testing; 3) reviewed the overall economics of an aggregate operation in the area; 4) examined the potential to transport the aggregate by water; 5) estimated transport costs; and 6) identified potential markets in Canada and the United States.

The compilation of these data is a critical first step in assessing to overall feasibility of mining aggregates in the Lake Superior area. More extensive and much more detailed analysis will be required before an actual business undertaking can be initiated.

Following is a summary of the primary results of the study.

- There are a number of sizeable igneous intrusions and diabase dikes and sills which exhibit the potential to produce high quality aggregate, based on published geological knowledge and a review of field characteristics.

- Selective aggregate quality testing indicates that many of the rock units identified are capable of meeting or exceeding high quality aggregate test specifications.

- Many of the candidate rock units occur within areas that exhibit reasonable local conditions with respect to work force and support infrastructure.

- There are 2 existing deep water ports in the study area capable of handling fully loaded bulk freighters. A number of candidate areas contain sites with potential to construct a new deep water shipping facility. Two existing docks and a number of undeveloped sites have the potential to be upgraded to provide some form of marine shipping facility.

- The per tonne cost of shipping aggregate from an eastern Lake Superior facility to several example receivers has been estimated: Chicago $11.85; Cleveland $10.30; Detroit $9.70; Toronto $11.30. Costs from western Lake Superior are estimated to be: Chicago $13.35; Cleveland $11.80; Detroit $12.20; Toronto $14.30. Prices are based on 2000 shipping rates and conditions. Additional ground transportation may be necessary between the receiving terminal and the consumer.

- The average selling price (f.o.b. the source) of high quality aggregate (granite and traprock) in the United States is currently $9.15 (CDN).

- The cost of manufacturing, marine transport and land transport for Lake Superior aggregate moving to the major Great Lakes ports is estimated to be in the order of $25 to $30 per tonne.

- The cost for high quality aggregate delivered in Toronto is in the order of $30 per tonne; several other centers are expected to see similar prices in the foreseeable future.

- There is an existing "niche" market for high quality aggregate materials in several centres, notably Detroit and Toronto.

- Prices for general quality aggregates are lower in all areas considered, but local demand/supply relationships suggest rising prices over the next 10 to 15 years.

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APPENDIX A

ADDITIONAL TEST DATA

APPENDIX – ADDITIONAL TEST DATA

POLISHED STONE VALUES

Polished Stone Value (PSV) testing was completed on the samples taken from Lake Superior. The PSV test is currently being developed as a test for high quality aggregate, but it is not currently a specification requirement in Ontario.

The fine scale texture, or micotexture, of an aggregate particle is one of 2 properties which contribute to the skidding resistance of asphalt pavements. The other property is macrotexture, but this is not dealt with here. Good microtexture may be thought of as the "rough sandpaper-like feel" of an aggregate particle surface (Rogers 1983). Microtexture developed by an aggregate is a function of the physical nature of the material and the environmental conditions where it is used.

A test used by MTO to evaluate microtexture is the Polished Stone Value (PSV) test. This test is an "accelerated polishing technique", which uses a "sliding pendulum to measure the frictional properties of the aggregate after 3 hours of abrasion with coarse emery sand, and 3 hours of polishing with a fine emery powder." The PSV test gives a value that normally ranges between 40 and 60 for most aggregates. Aggregate frictional properties are better the higher the PSV obtained in the test. Studies in Ontario have shown that the PSV is one of the most important aggregate characteristics affecting the skidding resistance of asphalt pavement.

The PSV test is not officially part of test specifications for high quality aggregates in Ontario. However, it is possible that the test will take on greater significance in the future. Therefore, PSV testing was included in the Lake Superior bedrock aggregate study. The PSV testing was completed at MTO's Downsview laboratory.

Seventeen samples from the Lake Superior candidate resource areas were tested for the PSV. The test results all fell within a relatively narrow range of 47 to 52, as summarized in Table A-1. MTO presently recommends that aggregates for skid resistant asphalt have PSVs greater than 50. Several of the Lake Superior samples meet or exceed this specification, indicating that there is a high potential to obtain high quality, skid resistant aggregates from the study area.

TABLE A-1: POLISHED STONE VALUES (PSV)

PHYSICAL EVALUATION AND ASSESSMENT OF BEDROCK AGGREGATE POTENTIAL

NORTH SHORE OF LAKE SUPERIOR

Candidate Resource Area	Field Sample Number	Laboratory Sample Number	Rock Type	PSV
1	1BR005	9082	Diorite	48
2	2BR014	9081	Granite	51
3	3BR018	9083	Granite	50
4	4BR084	9084	Granite	49
5	5BR078	9085	Diorite	52
5	5BR081	9086	Granite	52
7	7BR026	9087	Syenite	48
7	7BR030	9088	Syenite	48
9	9BR042	9089	Granite	49
10	10B043	9090	Granite	48
10	10B051	9091	Granite	50
11	11B053	9092	Diabase	52
12	12B073a	9095	Rhyolite	47
12	12B073b	9096	Anorthosite	52
13	13B061	9097	Diabase	49
14	14B064	9098	Granite	52
15	15B069	9099	Diabase	51

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

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